Significant Tornado Climatology for Lower Michigan

John Laurens and Randy Graham

National Weather Service

Grand Rapids, MI

GRR Severe Weather Seminar

March 22, 2004

Methodology

- Identified all F3 or stronger tornado events (i.e., days) occurring in central and/or southern lower Michigan from 1965 through 1991 (20 events).

- For each event, we analyzed 00Z (previous day), 12Z, and 00Z MSLP, 850 MB T, 850 MB Winds, 500 MB Heights, and 250 MB wind charts.

- After detailed analysis and comparing and contrasting each of those charts for each event, we were able to classify 17 of the 20 events into 3 unique pattern types which produce F3 or stronger tornadoes across lower Michigan.

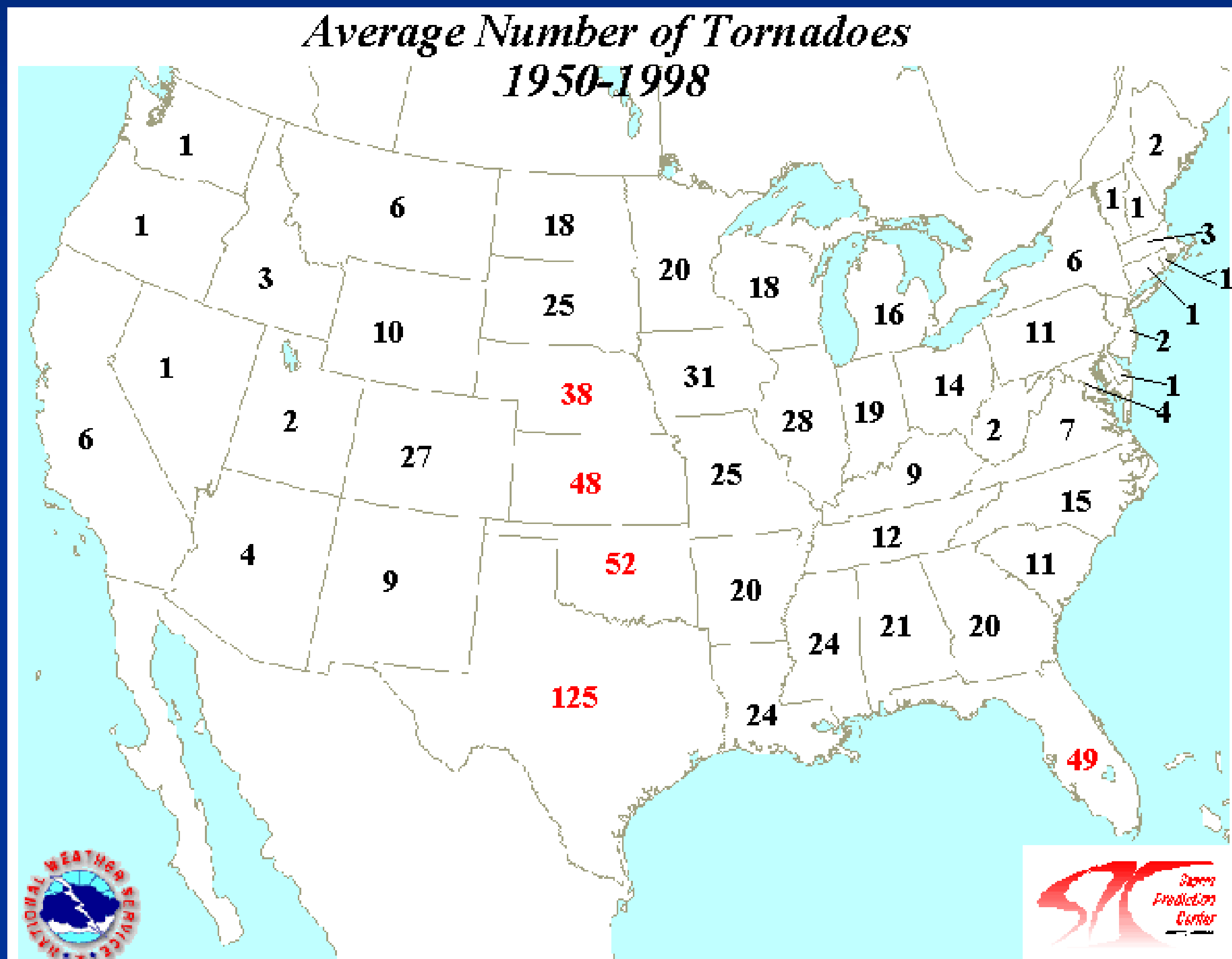
Methodology (cont'd)

- 7 events were categorized as Type 1; 5 were categorized as Type 2; and 5 were classified as Type 3 events.

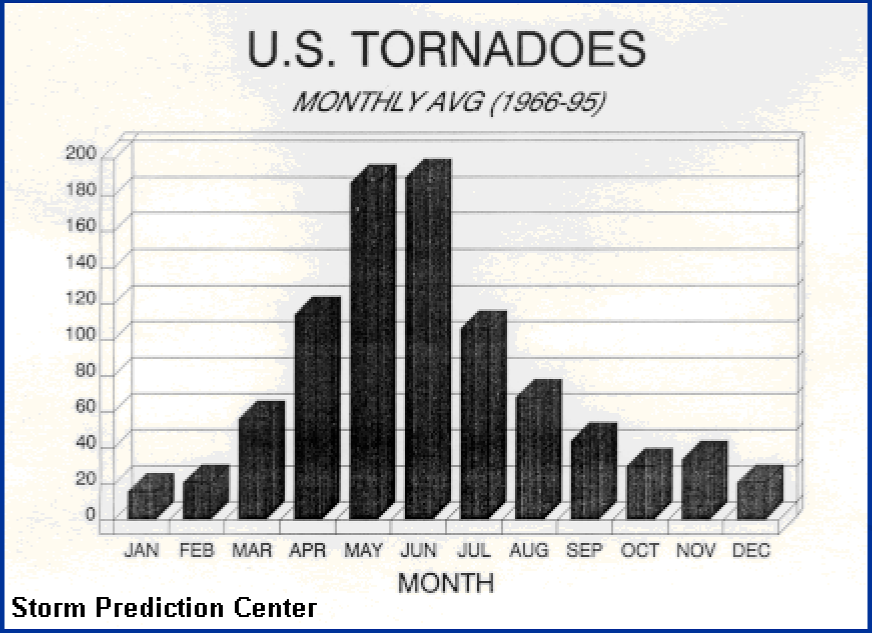
- The remaining 3 events were outliers which would not fit into any of the aforementioned pattern types.

- Using reanalysis software we generated composites of MSLP, 850 MB T, 850 MB Winds, 500 MB Heights, and 250 MB wind fields for each pattern type.

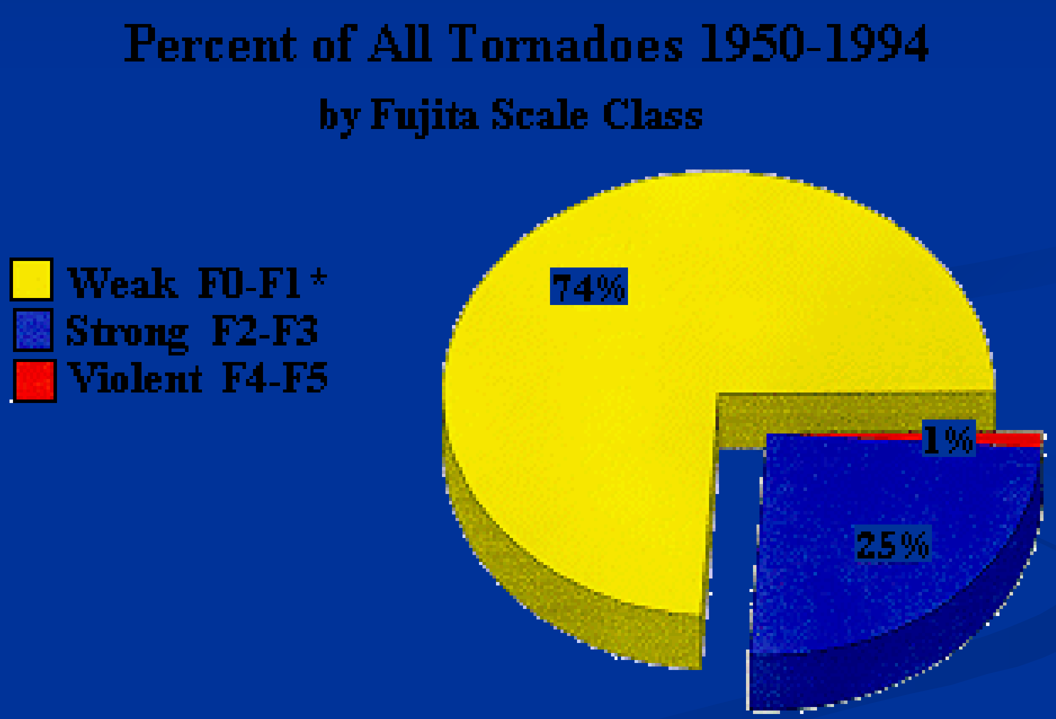
Average Number of Tornadoes by State 1950-1998



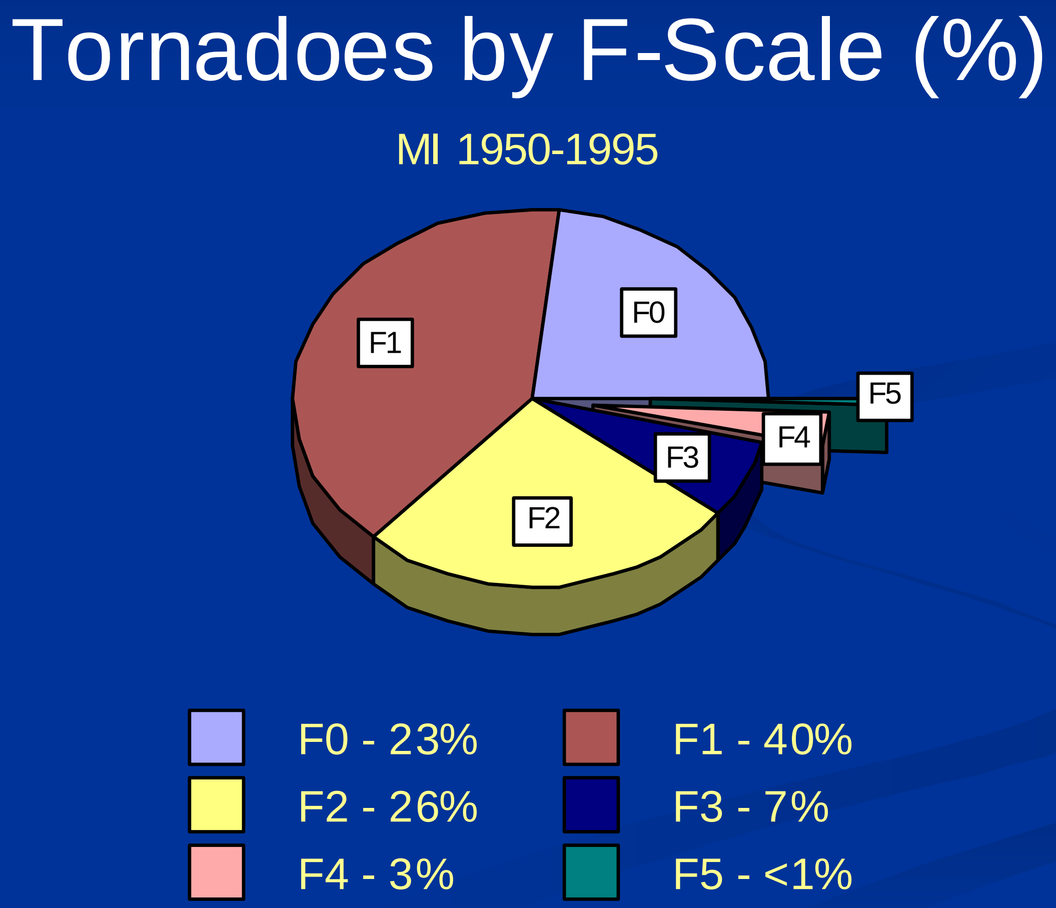
Monthly Averages of U.S. Tornadoes (From 1966-1995)



Percent of Tornadoes by Fujita Scale Class – United States



Percent of Tornadoes by Fujita Class Scale - Michigan



Official NOAA Michigan Tornado Statistics, 1953 – 1991

- Michigan had 32 killer tornadoes between 1953 and 1991. For all states in the U.S., this ranks 13th for killer tornadoes.

- Michigan had 236 tornado deaths from 1953 to 1991. This ranks 4th in the United States for the highest number of fatalities by state.

Michigan Tornado Statistics – From NCDC

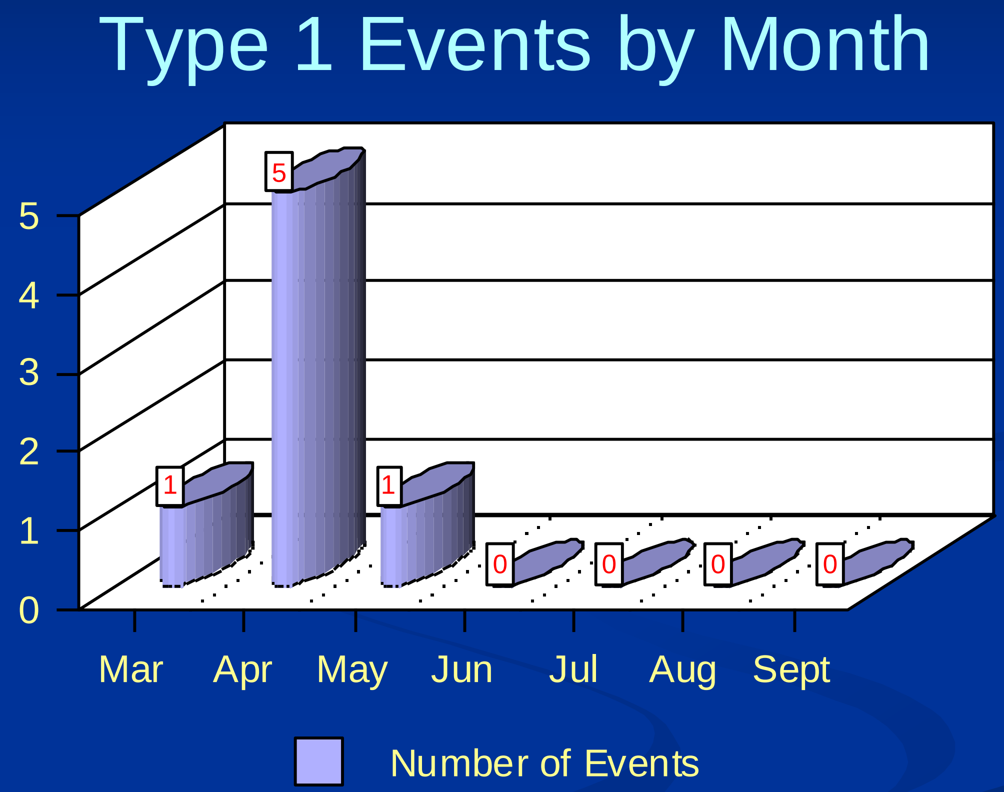
- We took a preliminary look at a few statistics and found that there were 97 F3 or larger tornadoes in MI between 1951 and 2000. That constitutes 11% of all MI tornadoes (918) occurring between 1951 and 2000.

- 4 of 7 F5's occurring in that 50 year time span struck in April.

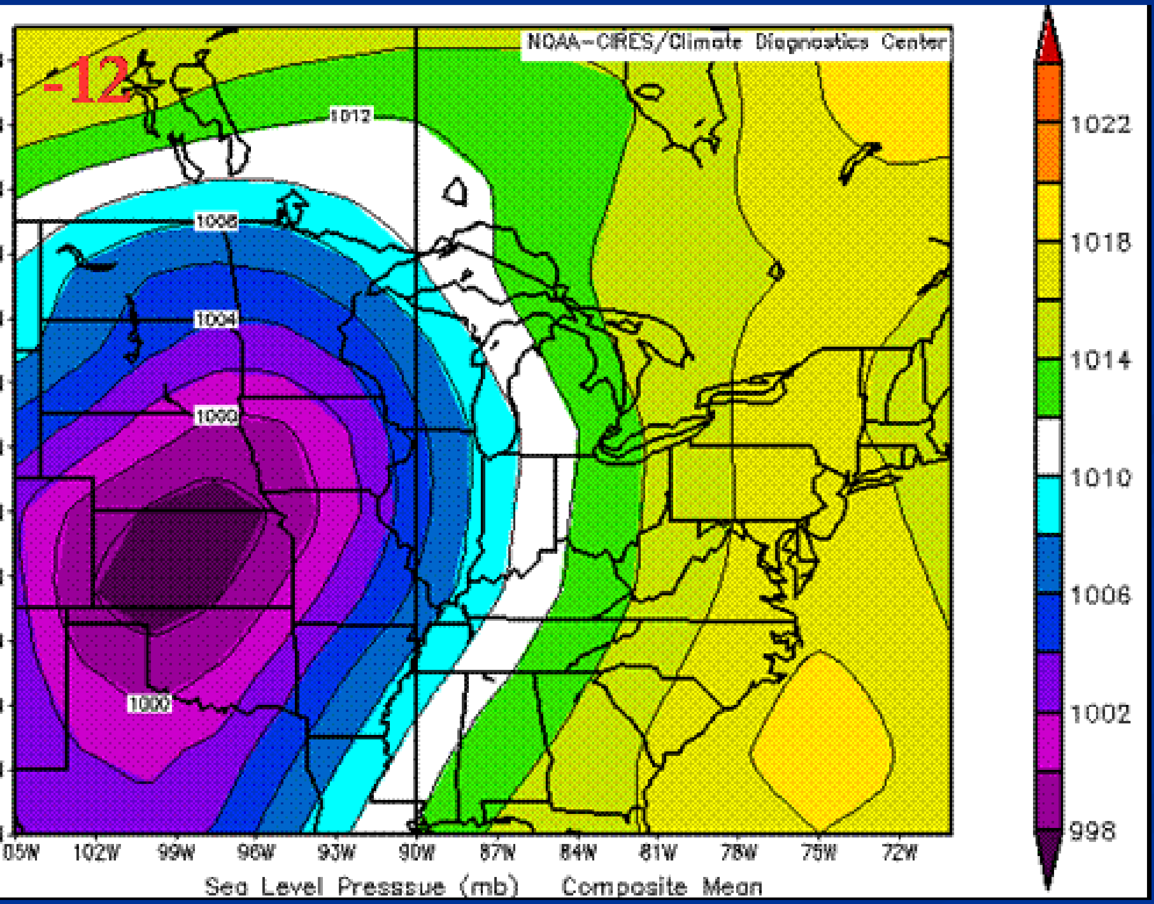
- 27 of 30 F4's occurring in that 50 year time span struck in March through May.

Type 1 Events

- 7 Events
- All occurred in March, April, or May.



MSLP Loop – Type 1



In the typical Type 1 scenario, an intensifying surface low tracks from the central plains on 00Z the previous day to the IA/MO border at 12Z on the day of the event. The low then tracks to northern lower MI by 00Z.

MSLP – Type 1

- Range of low tracks for each individual event was fairly wide. The most important note is that in 6 of the 7 events, the low passed west of ORD (one went over ORD).

- Gulf of Mexico is wide open in Type 1.

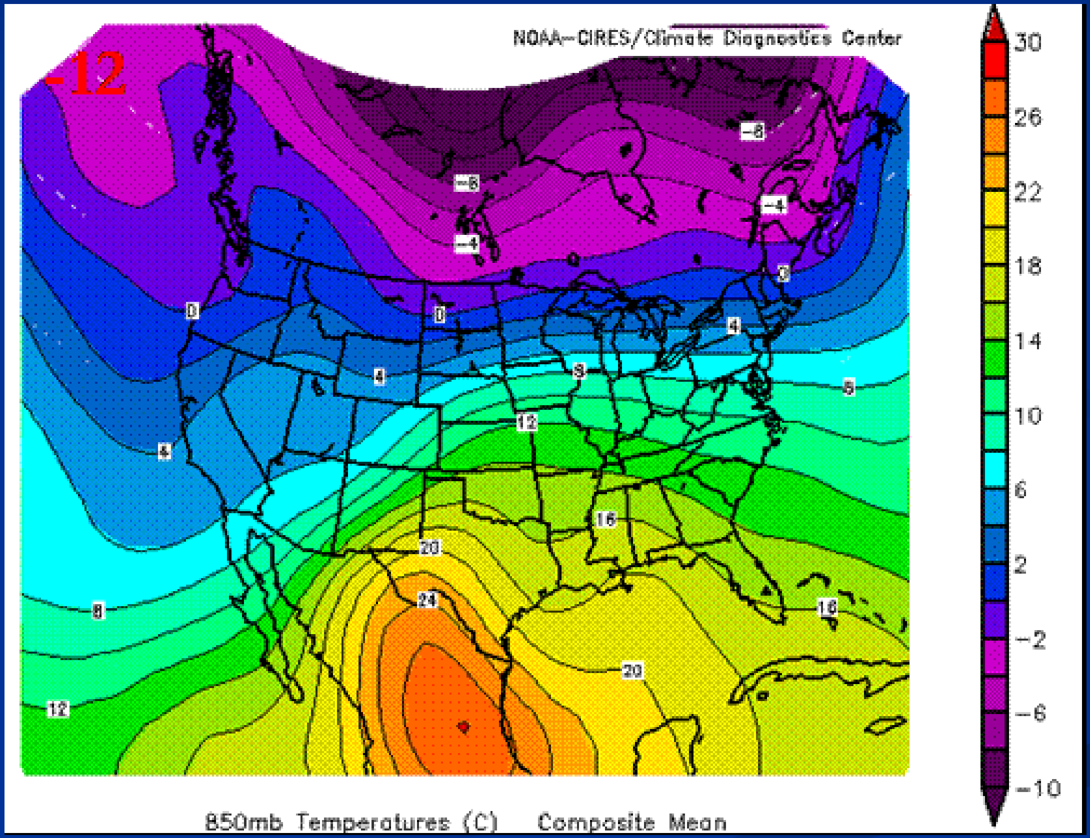
- Note the strength of the surface low.

Surface Fields – Type 1

- Temperatures at 1800 UTC across southern lower MI were typically in the upper 50s F to the upper 60s F. Range was from the mid 40s F to the lower 70s F.
- Dewpoints were generally in the mid 50s F. They ranged from the mid 40s F to the lower 60s F.
- Dewpoint Depressions were typically in the 8-14 F range.

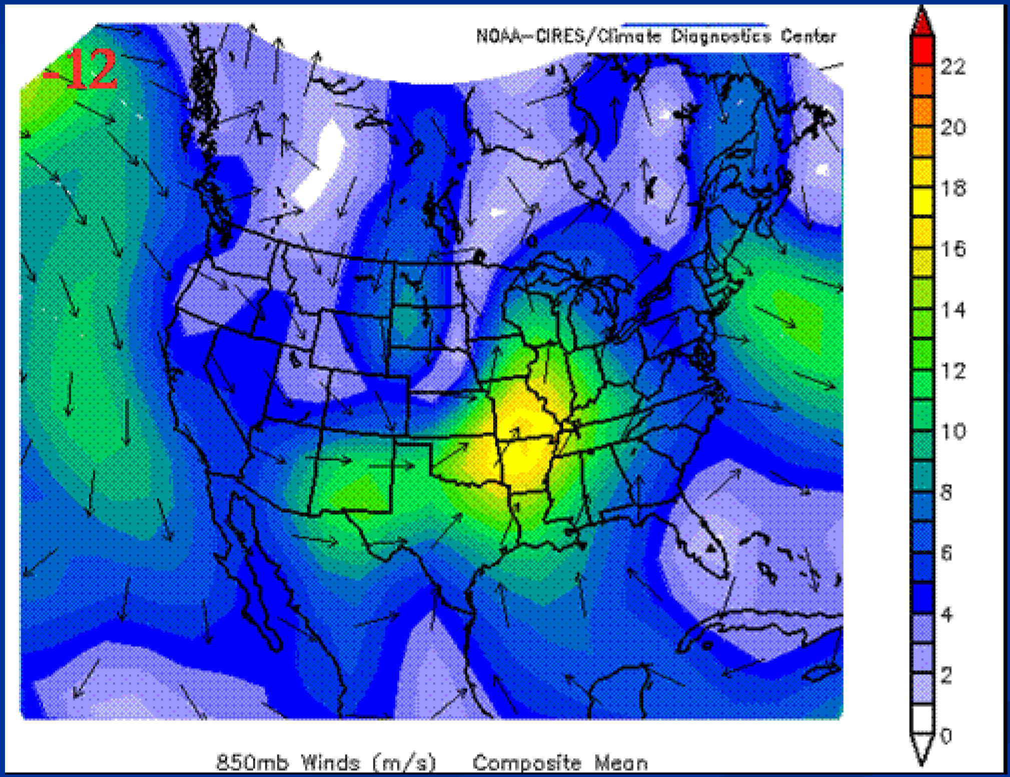
850 MB T – Type 1

- Thermal pattern amplifies sharply over 24 hour time period
- Strong WAA SE of lower MI. Strong CAA into the northern plains.



850 MB Winds

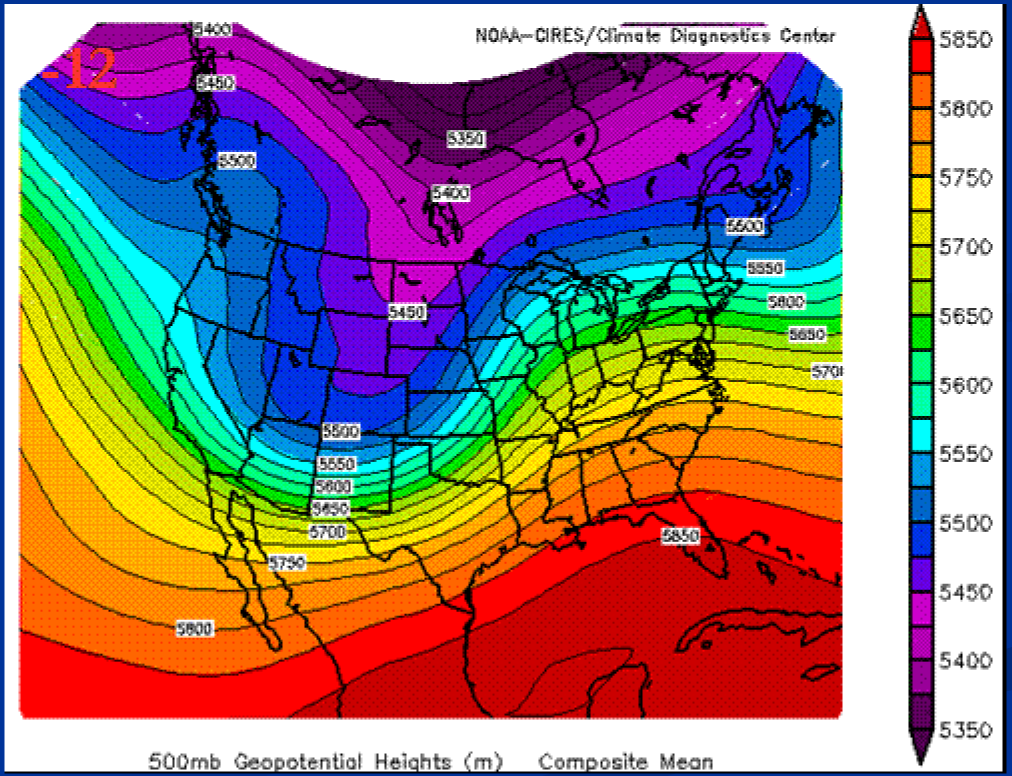
850 mb wind fields increase markedly as the core of the strongest 850 winds moves northeast. 850 mb wind speeds get up to around 40 knots across southern lower Michigan at 18Z.



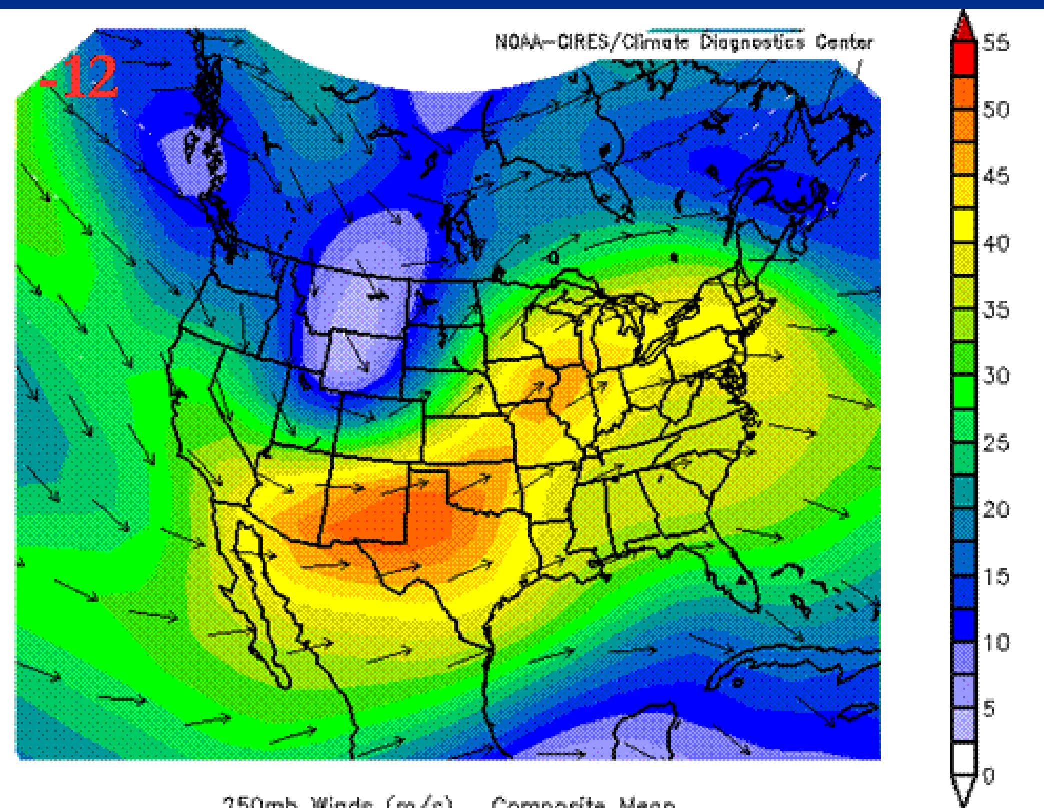
500 MB Heights

Nice phased upper pattern with ridge over the east and deep trough to our west. Upper level vort maxes pinwheeling around the base of the trough over New Mexico, Texas and the southern Plains states will move northeast right towards lower MI.

500 height values fall pretty significantly over lower MI in this 24 hour time period as the upper trough axis approaches.



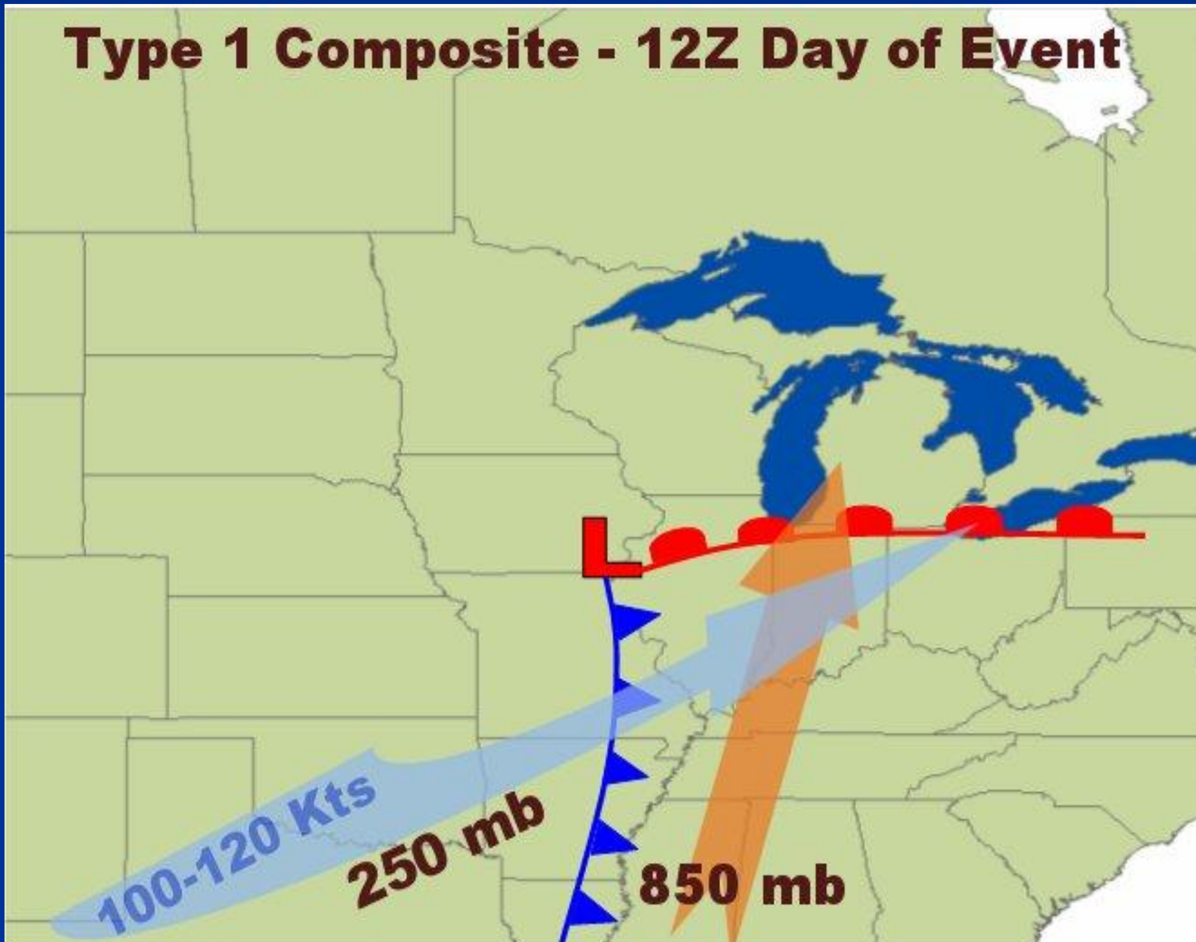
250 MB Wind – Type 1



- The strongest jet of the 3 pattern types

- 100 kt jet over southwestern U.S. becomes a 120-130 kt jet into the OH valley. Nose of jet right into southern lower MI.

Type 1 - Surface and Upper Air Composite



In the VORTEX-95 study (Markowski 1998a) they found that the majority of significant tornadoes occurred within 30 km of a readily identifiable surface boundary. The majority of these occurred on the cool side of the boundary.

In our Type 1 cases, backed surface winds north of the warm front contribute to the significant low level vorticity in the storm environment.

Generating Composite Analyses

- Looked at 00Z upper air soundings from International Falls, St Cloud, Green Bay, Peoria, Sault Ste. Marie, Flint, and Buffalo.

- Using SHARP we recorded observed values of CAPE, CIN, BRN Shear, 0-3 km SRH, 0-1 km SRH, EHI, LFC (m), LCL (ft), forecast storm motion.

- Averages were created for these values for each pattern type at each sounding location. Then utilized Arcview to create composite analysis graphics for each parameter.

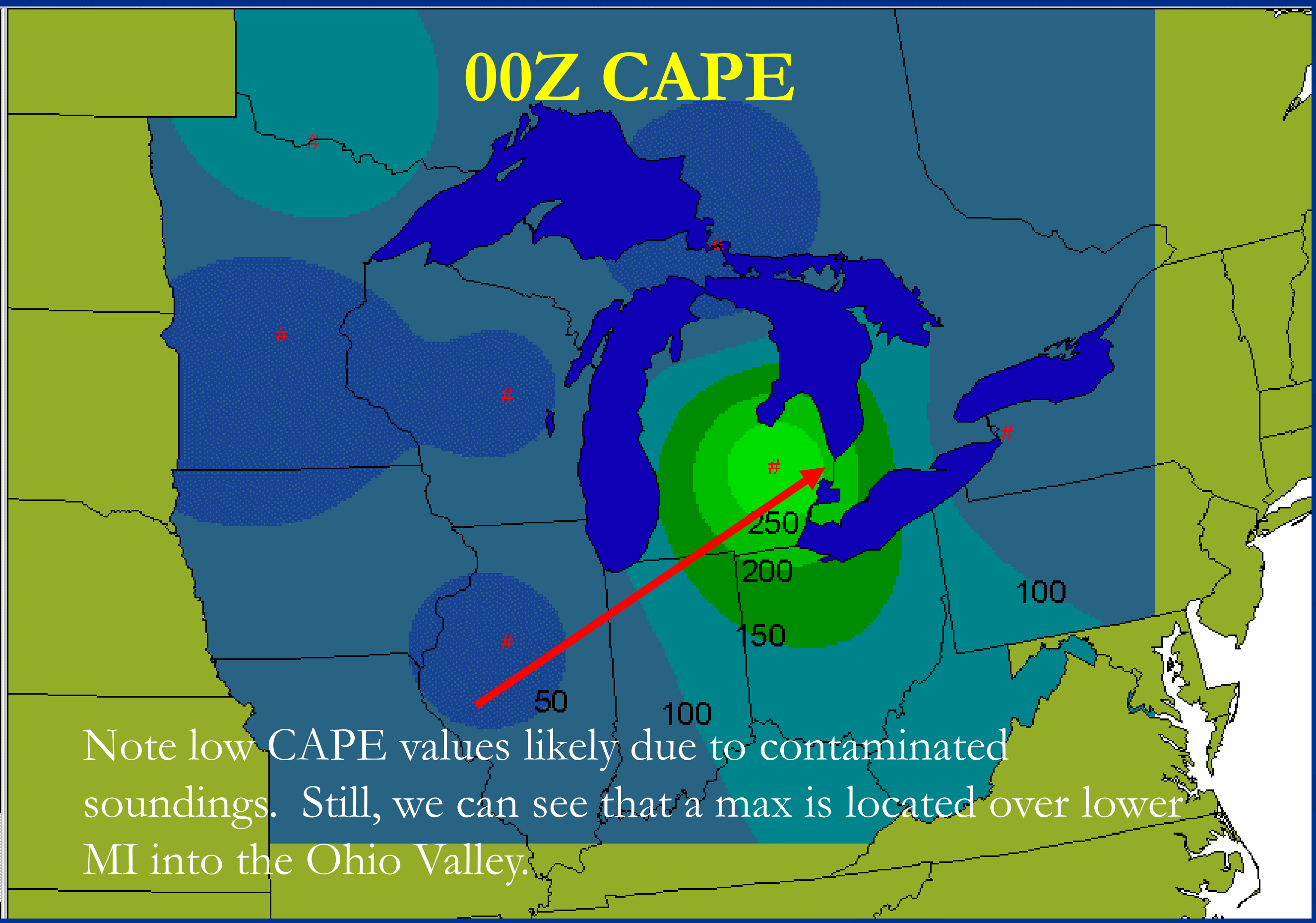
CAPE

- CAPE values often exceed 2000 j/Kg in environments which support strong supercells.

- Of course, supercells frequently occur in low bouyancy, high shear environments. In fact, one study found that most supercells occur with CAPE values of less than 1500 J/kg. Remember, we must consider the vertical distribution of CAPE and not simply the total CAPE (this has to do with parcel acceleration which is important to the ingestion of low level vorticity).

- Shear is a much better discriminator of supercell versus non-supercell environments. Don’t get too hung up on CAPE.

Type 1 - CAPE (Pmax)



Note low CAPE values likely due to contaminated soundings. Still, we can see that a max is located over lower MI into the Ohio Valley.

On average CAPE values were only 150-250 J/kg at 00Z across lower MI.

However, soundings modified using representative surface data from around the time of the tornado events yielded CAPE (Pmax) values around **630 J/kg**.

CIN

- CIN represents the amount of negative buoyant energy available to inhibit or suppress upward vertical acceleration, or the amount of work the environment must do on the parcel to raise the parcel to its LFC.

- CIN basically is the opposite of CAPE, and represents the negative energy area (B-) on the sounding where the parcel temperature is cooler than that of the environment. The smaller (larger) the CIN is, the weaker (stronger) must be the amount of synoptic and especially mesoscale forced lift to bring the parcel to its LFC.

- High CIN values in the presence of little or no lift can cap or suppress convective development, despite possibly high CAPE values. Remember, CAPE is the "available potential" energy. That energy must be released to become "kinetic" energy to produce thunderstorms.

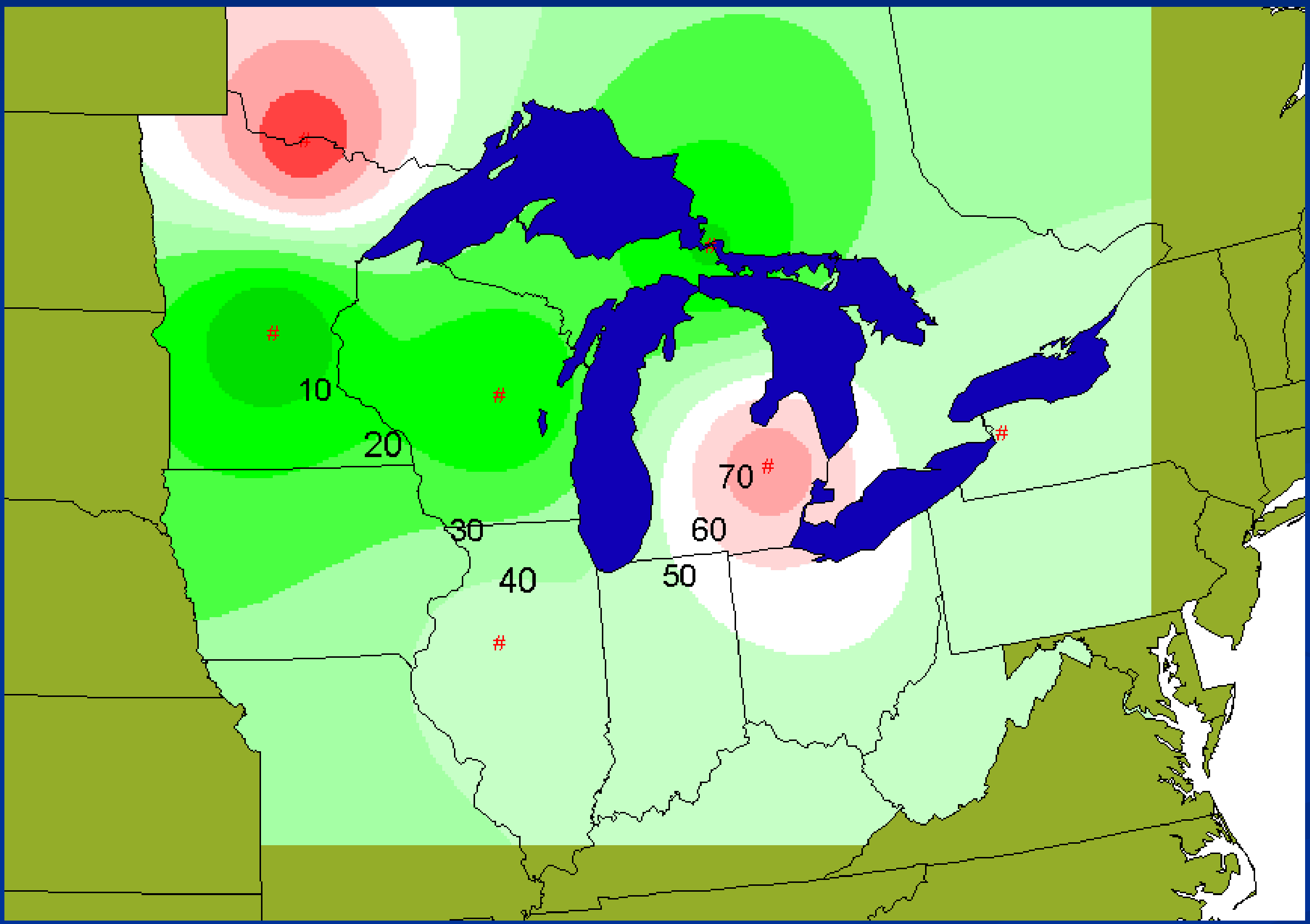
- Rasmussen and Blanchard (1998) found that 75% of tornadic classic supercell environments had CIN < 21 J kg-1 and 60% of non- tornadic supercell environments had values greater than this.

CIN Values

Here are some rough guidelines for assessing the amount of CIN in the environment.   CIN values over 100 J/kg would significantly reduce the tornadic potential.

< 50 J/kg	Very Favorable
50 - 80 J/kg	Favorable
80 – 150 J/kg	Unfavorable
> 150 J/kg	Very Unfavorable

Type 1 - 00Z CIN



CIN values are below 80 J/kg across the entire domain. Although these are not ideal, with sufficient forcing these CIN values could be overcome.

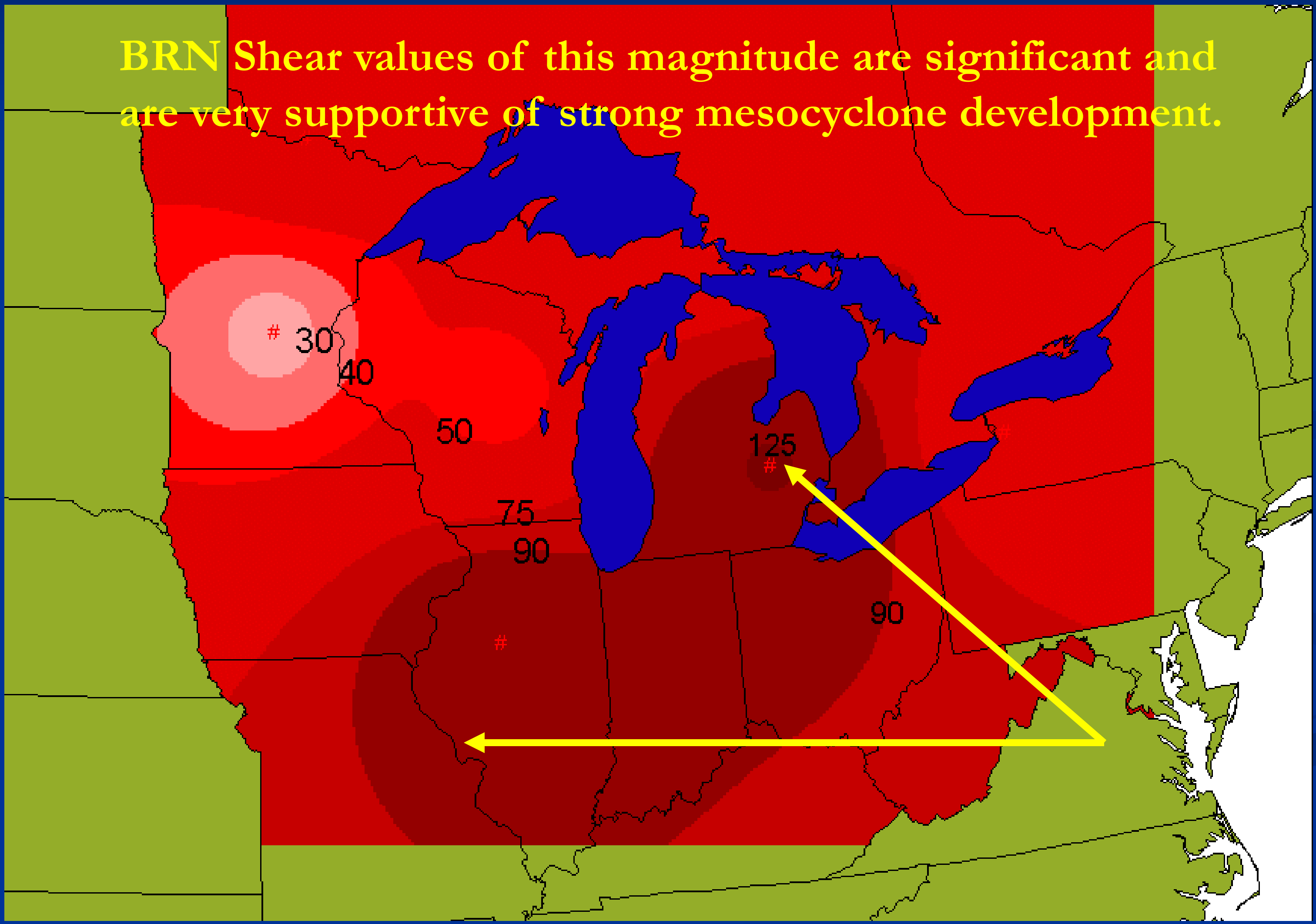
BRN Shear

Formula: Vector difference between the density weighted 0 to 6 km wind vector and the 0 to 500 m wind vector.

- Shows fairly good utility in distinguishing storm morphology (supercell vs non-supercell), mid level mesocyclone intensity, and storm relative surface flow (Jahn and Doegemeier, 1996)

BRN Shear Value	
40 to 140 m2/s2	Potential for Significant Supercells
35 to 40 m2/s2	Potential for marginal supercell events (Thompson 20000)
< 35 m2/s2	Outflow dominated storms
Note: BRN Shear < 40 m2/s2 and SRH > 100 m/s Associated with Bow Echoes	

Type 1 – 00Z BRN Shear



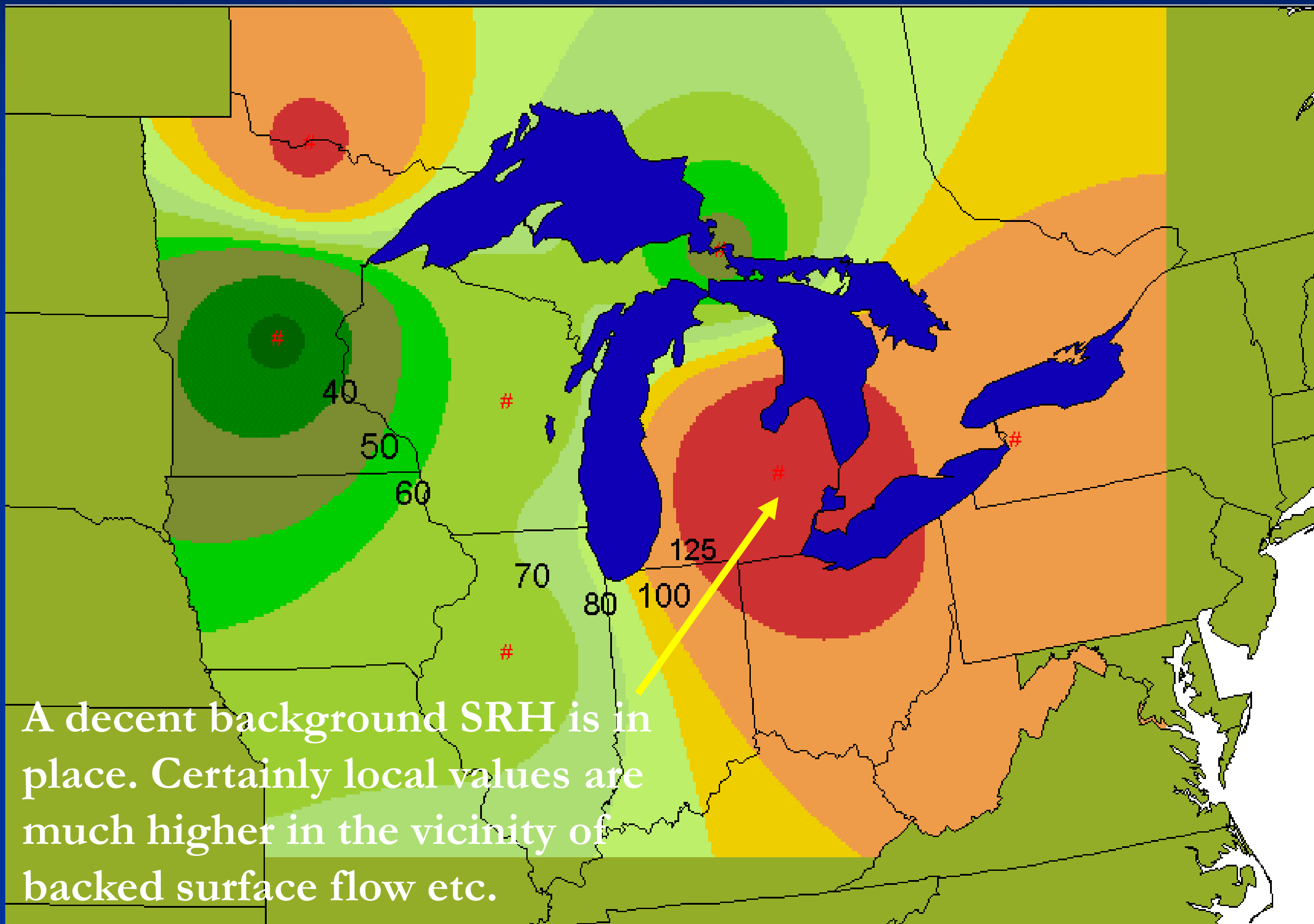
0-3 km SRH

- Formula: The vertically integrated value of horizontal vorticity advection. It is a measure of how much streamwise vorticity is being ingested into a storm and is a measure of rotation potential.
- Generally not as good as mean vertical shear (0-6 km Shear, BRN Shear etc) in determining the potential for supercells since it requires a storm motion ahead of time (Weisman, 1996)
- Varies by two to three orders of magnitude spatially. Can be much higher in the inflow of supercells (Markowski et al 1998a)
- Once supercells are forecast by mean winds, then SRH can give an idea of how likely tornadoes are.
- The larger the amount of SRH, the better the chance for tornadoes. However, there are no clear boundaries.

0-3 km SRH

0-3 km Storm Relative Helicity	
> 100 m2/s2	Supercells possible (Davies Jones et al. 1990, Moller et al 1994)
> ~150 to 200 m2/s2	Right moving, significant supercells favored with large CAPE (Thompson, 2000)
> 300 m2/s2	Right moving, significant supercells favored with normal CAPE (Thompson, 2000)
> 500 m2/s2	Proposed minimum requirement for tornadoes to occur without augmentation from external boundaries (Markowski et al 1998b)

Type 1 – 00Z 0-3 km SRH

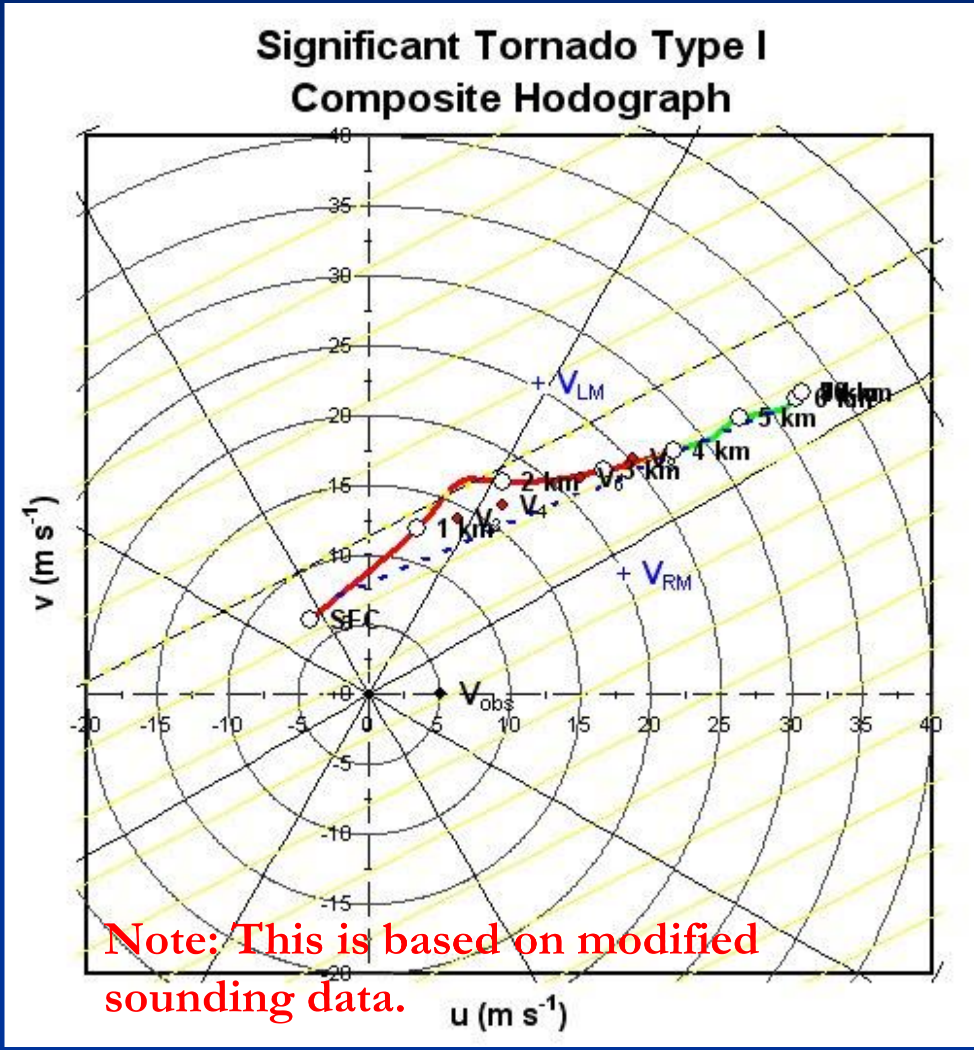


A decent background SRH is in place. Certainly local values are much higher in the vicinity of backed surface flow etc.

0-1 km SRH

- Markowski (1998b) found that 0-1 km SRH is likely more important for tornado development than 0-3 km SRH.
- In environments associated with significant tornadoes (> F1) the 0-1km SRH was typically greater than 50% of the 0-3km SRH.
- Environments with supercells, but no significant tornadoes (F1 or less) the SRH tended to be more evenly distributed in the 0-1, 1-2, and 2-3 km layers.
- Research currently ongoing at SPC (Rich Thompson, personal communication) indicates that supercell environments that produce F2 or greater TORs exhibit *0-1 km SRH > 100 m^2/s^2 ~75% of the time*.

Type 1 - Composite Hodograph



Used wind from representative surface observation near the time of the tornado events to modify upper air sounding.

0-1 km SRH 102 m^2/s^2

0-3 km SRH 225 m^2/s^2

0-6 km Shear 37 m/s

Energy-Helicity Index (EHI)

(Rasmussen and Blanchard, 1998)

Designed to pick up on significant tornado potential in both cool season (low CAPE, high shear environments) and warm season (high CAPE, low shear) environments.

EHI = [CAPE (Hs-r)] / 160,000 EHI is a dimensionless number.

This is a parameter that combines 0-2 km SRH and CAPE.

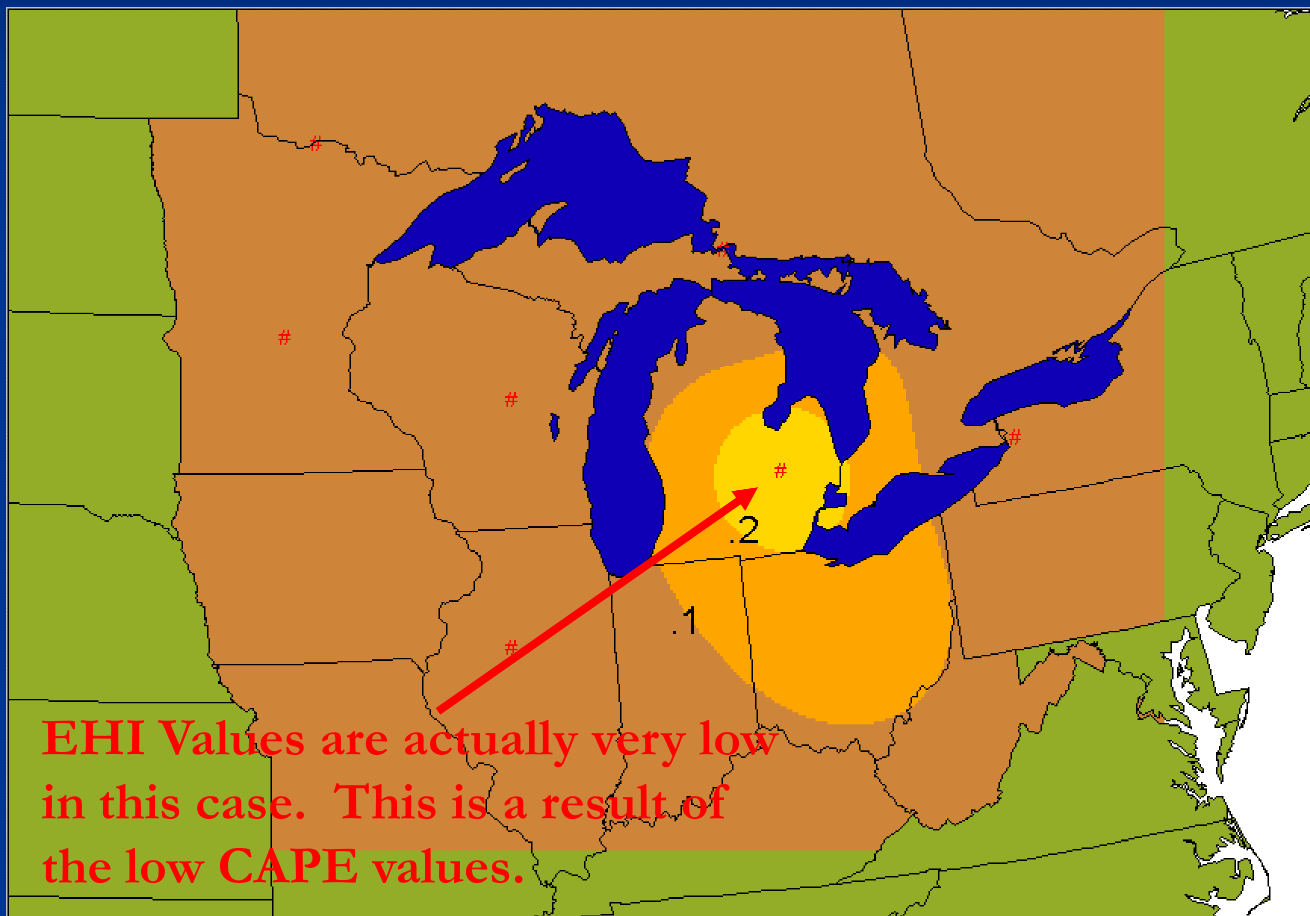
EHI

- CAPE and storm-relative helicity both play an important role in the development of a strongly rotating convective updraft.
- CAPE signifies the amount of buoyant energy available, while S-R helicity encompasses the effects of environmental vertical wind shear and storm motion on thunderstorm type and evolution.
- An intense rotating updraft can form with relatively modest CAPE if the vertical wind shear and storm-relative inflow are significant. On the other hand, relatively low S-R helicity usually can be compensated by high instability to produce a rotating updraft.
- The EHI attempts to combine CAPE and S-R helicity into one index to assess the potential for supercell and mesocyclone development. High EHI values represent an environment possessing high CAPE and/or high S-R helicity.

EHI Table

Energy-Helicity Index	
< 1.0	Supercells and tornadoes unlikely in most cases, but be aware of convective interactions and shear zones that could make EHI values unrepresentative.
1.0 to 2.0	Supercells and tornadoes are possible but usually tornadoes are not of violent or long-lived. Can get non-supercell/shear vorticy tornadoes near the leading edge of bow echoes/LEWPS.
2.0 to 2.4	Supercells more likely and mesocyclone-cyclone tornadoes possible.
2.5 to 2.9	Mesocyclone-induced supercellular tornadoes more likely.
3.0 to 3.9	Strong mesocyclone-induced tornadoes (F2 and F3) possible.
> 4.0	Violent mesocyclone-induced tornadoes (F4 and F5) possible.

Type 1 – 00Z EHI



EHI Chart

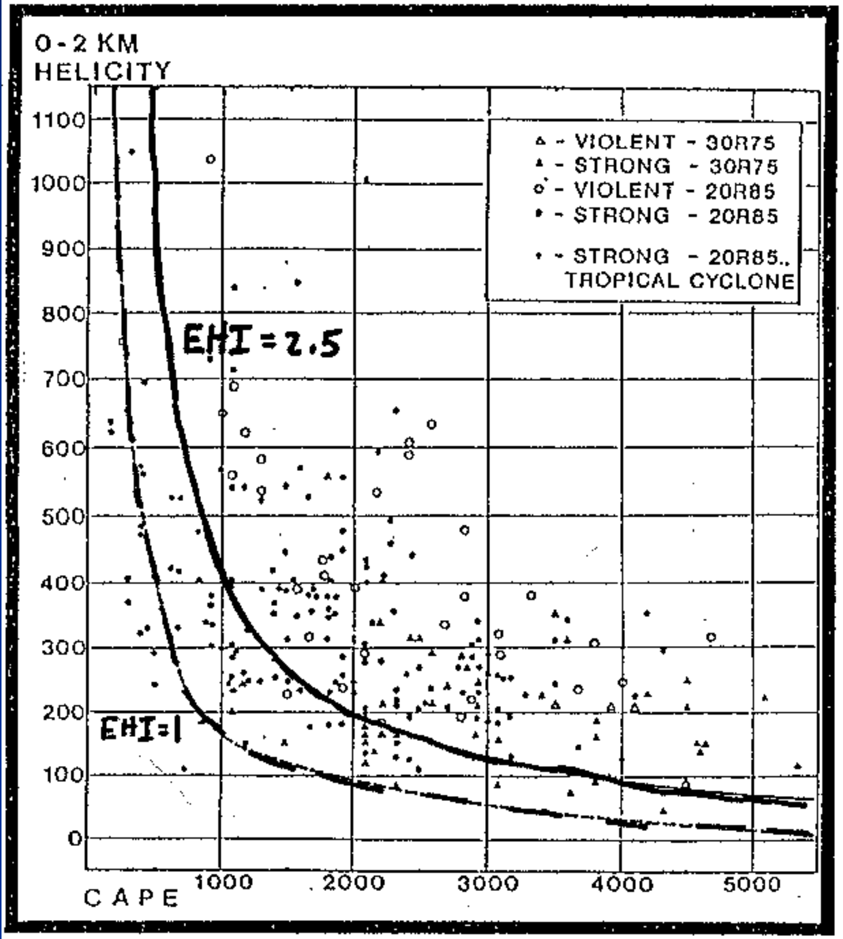


Fig. 1. Scatter diagram from Johns et al. (1993) showing distribution of 0-2 km AGL helicity and CAPE (using mean temperature and moisture in bottom 100 mb) for 242 tornado cases during 1980-1990. Dashed curve is EHI = 1.0; solid curve is EHI = 2.5 (see equation in text). Reproduced from Johns and Doswell (1992), curves added.

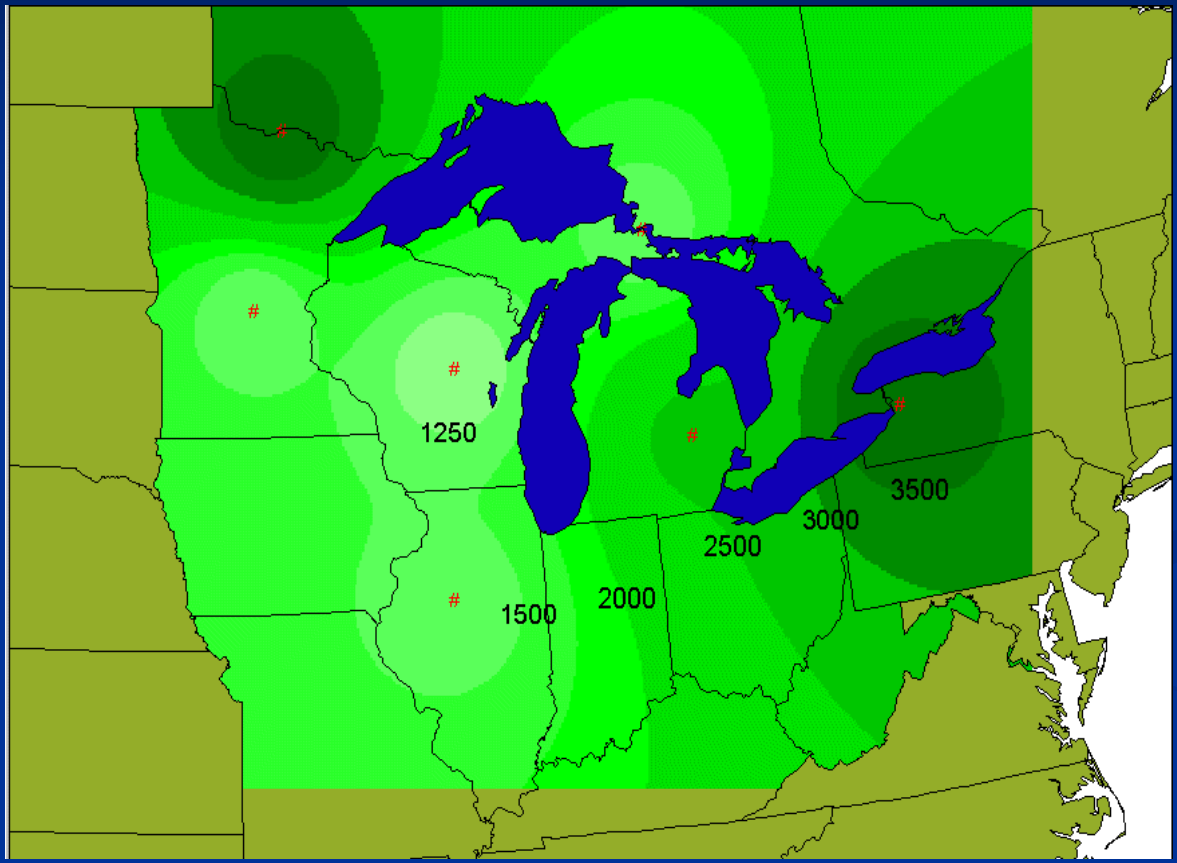
EHI chart from 0-2 km Helicity and CAPE (mean parcel in the lowest 100 mb).

Lines are EHI = 1 and EHI=2.5.

LFC Info

- Recent research results suggest that tornadoes (especially strong tornadoes) become more likely with supercells when LFC heights are less than 2,000 m (~6,500 ft) AGL (Thompson 2001).
- A study looking at 83 cases by Davies (2002) found that 82% of tornadic supercells had LFC Heights < 2000 m and 67% < 1500 m.

Type 1 – LFC Heights (m)



On average 00Z LFC values were 2000-2500 m across lower Michigan.

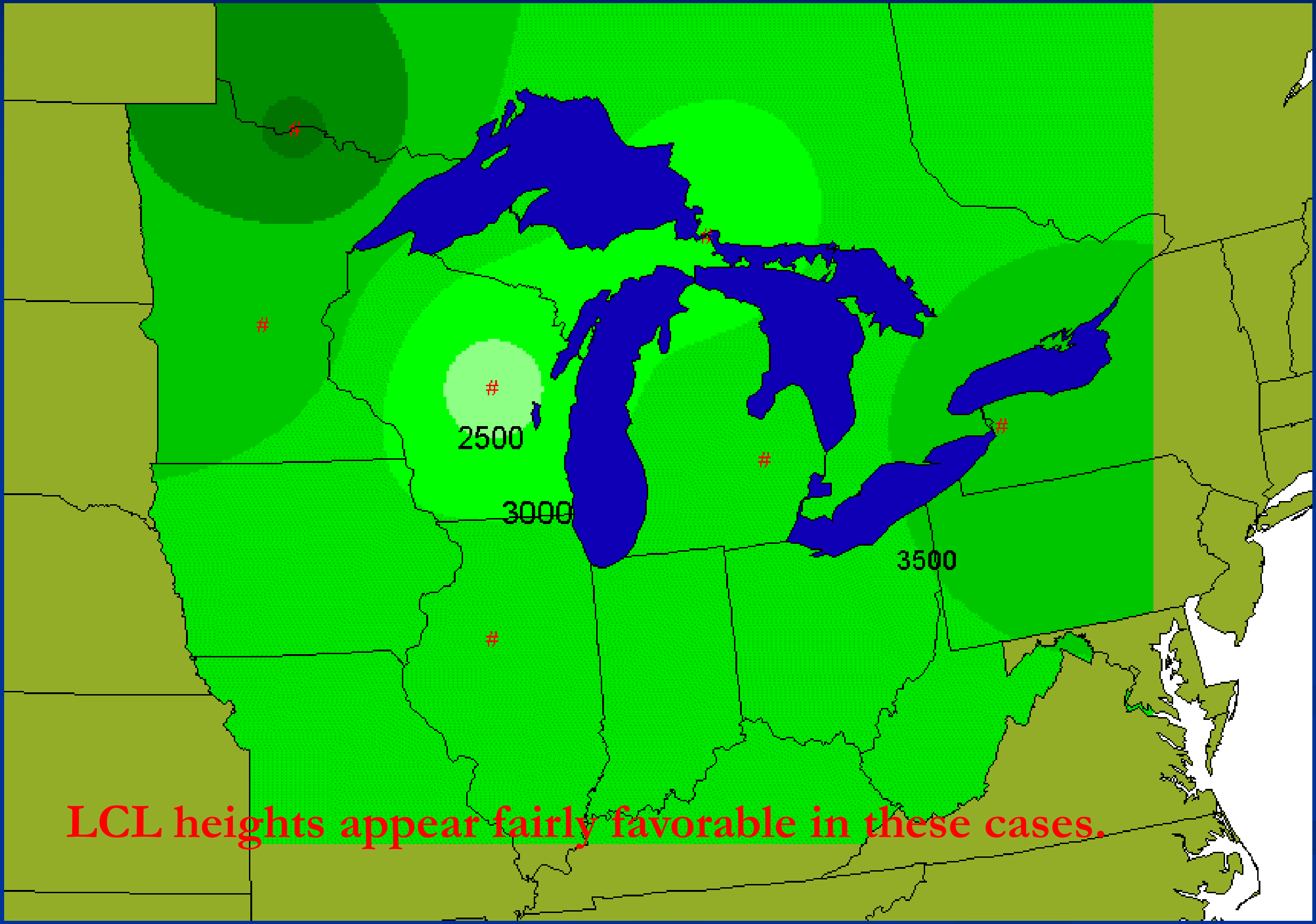
Soundings modified using representative surface data from around the time of the tornado events yielded LFC heights around **2100 m**.

LFC heights can be substantially lower than the 'background' environmental LFC in the vicinity of outflow boundaries etc.

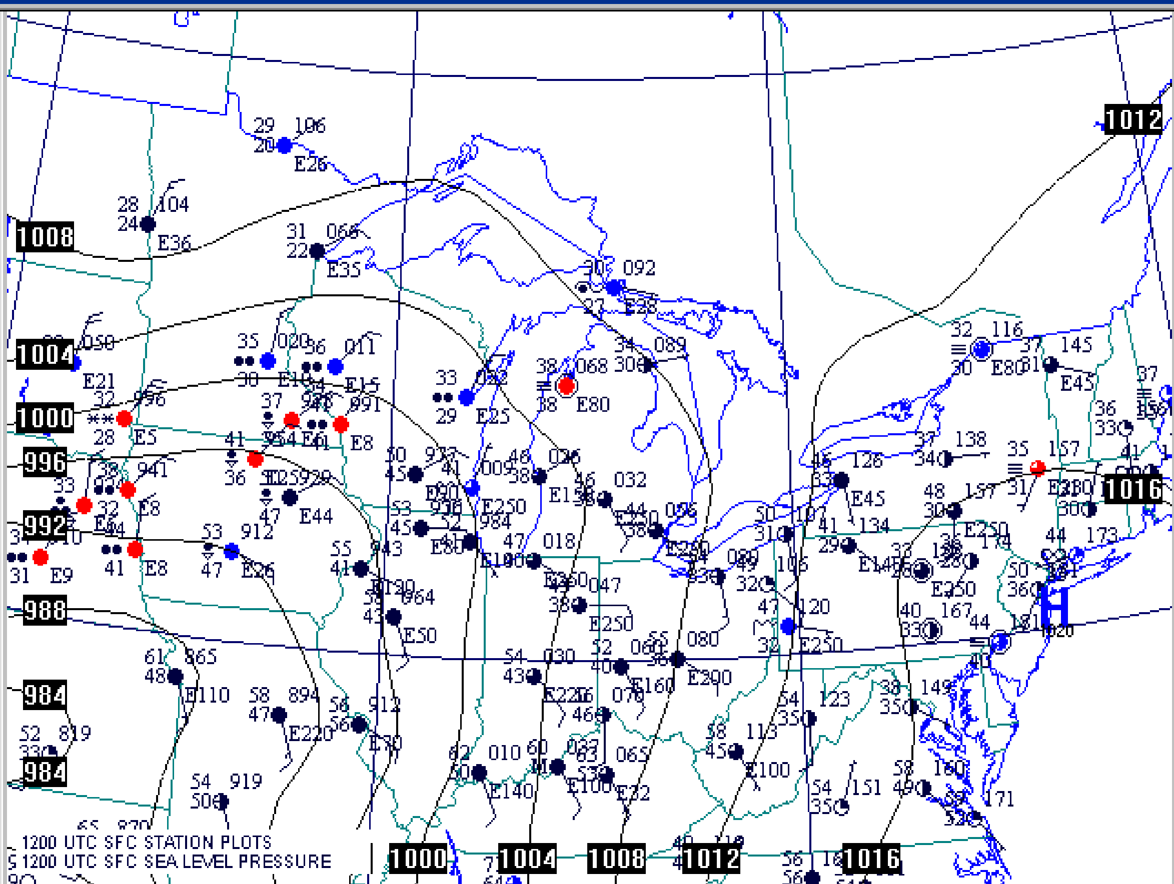
LCL Info

- Lower LCLs imply greater moisture content in the atmosphere below the cloud base than if the LCL is higher.
- In a study of nearly 3,000 supercells in 1992, more than half the significant tornadoes were associated with LCL's below 2,600 ft while more than half of the non-tornadic supercell soundings had LCLs above 4,000 ft (Rasmussen and Straka, 1998).

Type 1 – 00Z LCL (ft)

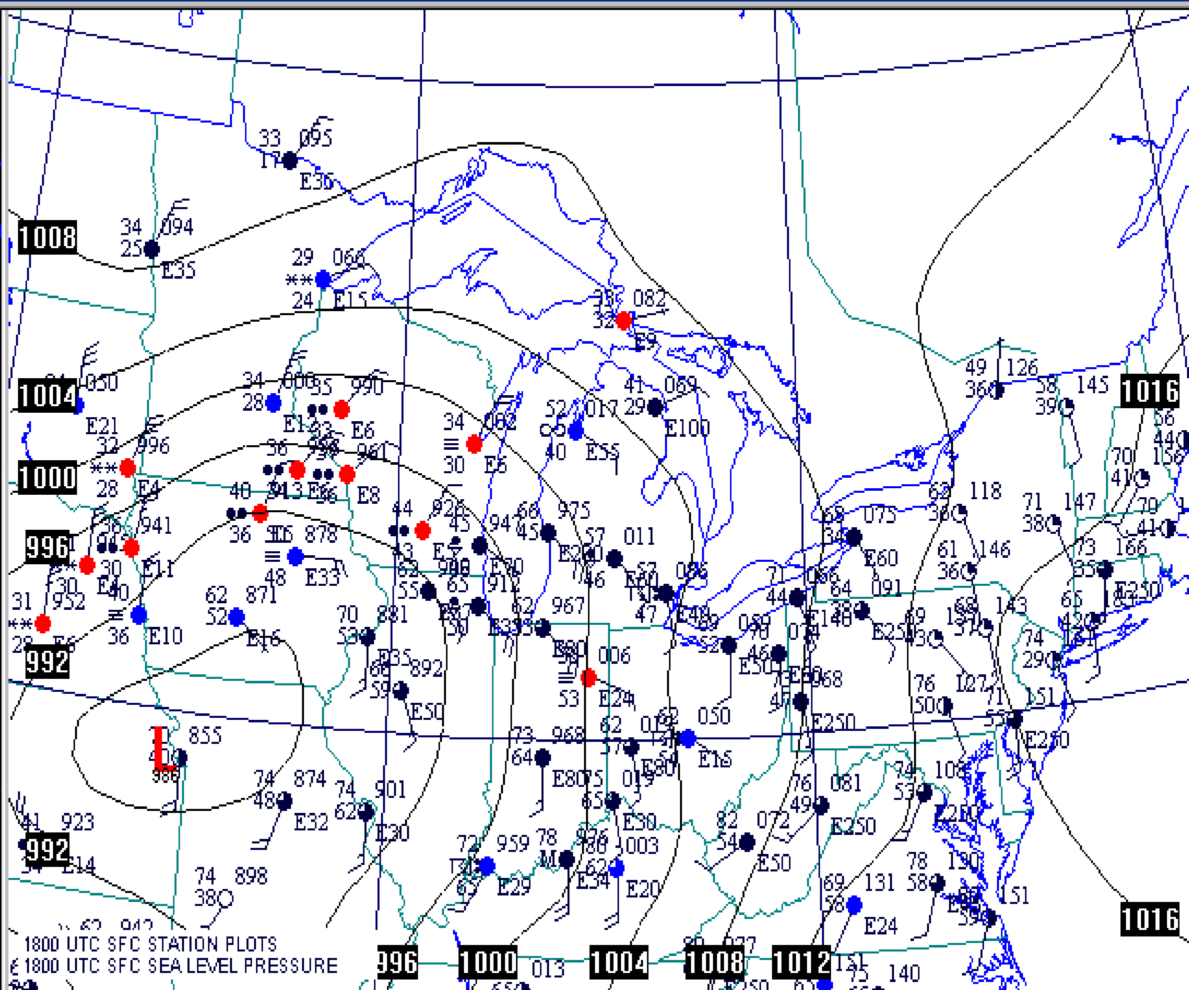


"Classic" Type 1 Event: 4/3/74 @ 12Z



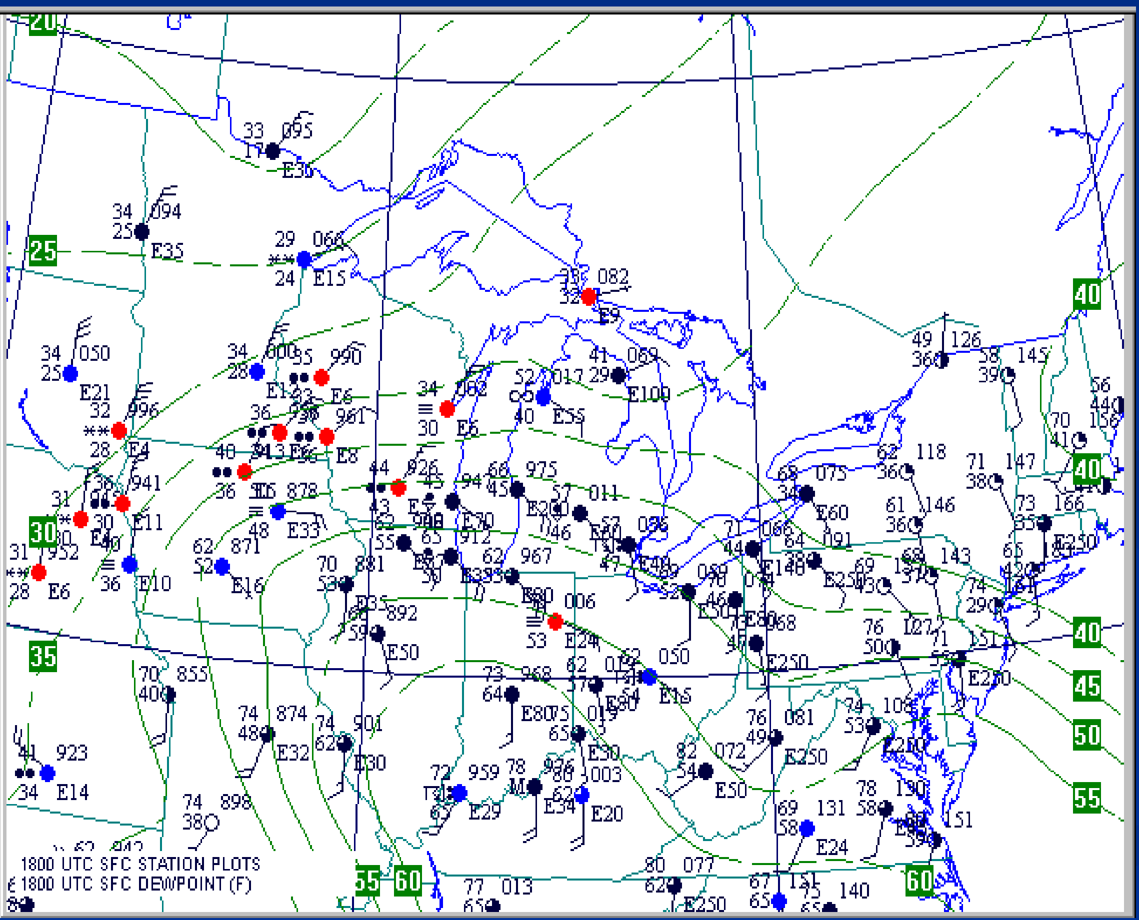
- Strong warm front from roughly BIV east to GRR and LAN at 12Z
- Intense low pressure over Kansas

Type 1: 4/3/74 @ 18Z



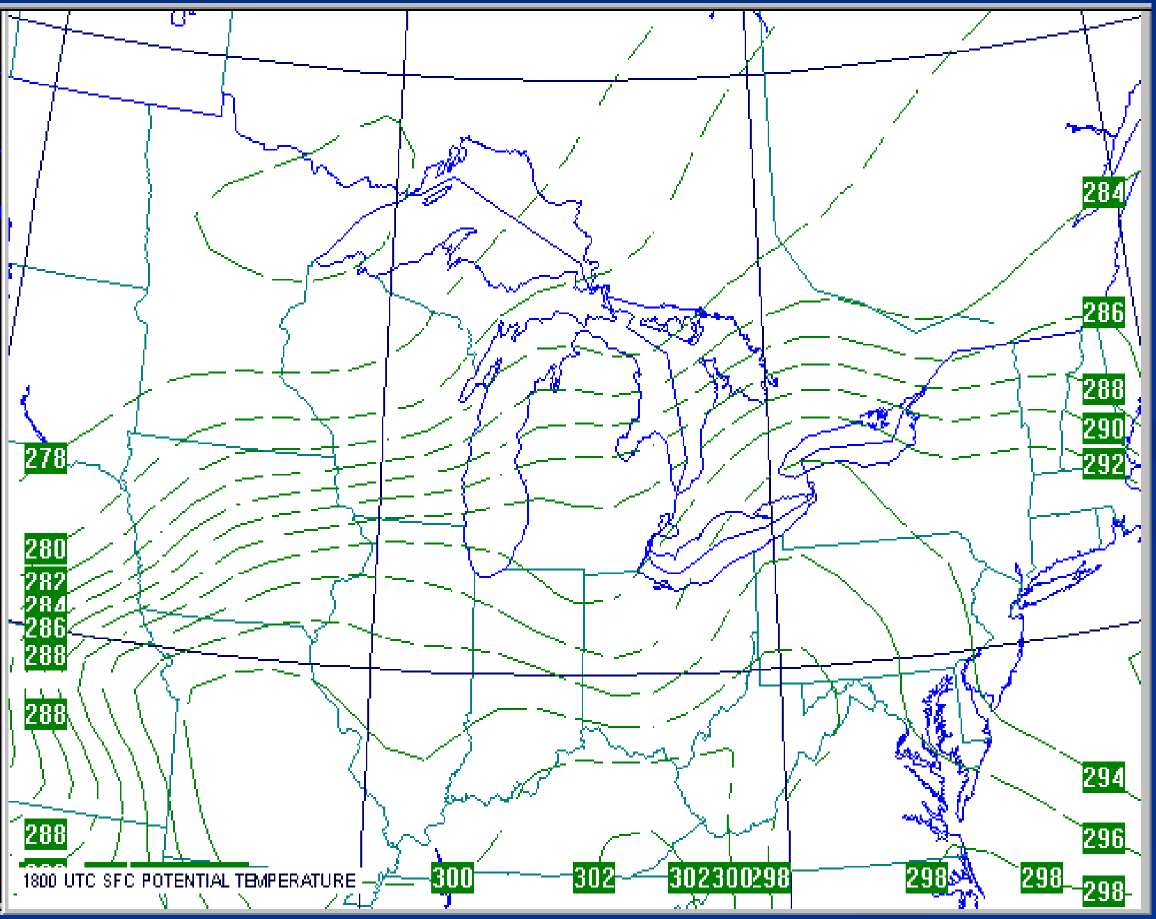
- Warm front lifting very slowly north to near MKG east to MBS by 18Z
- Very strong sfc low into northern MO/southern IA
- Dew point has jumped from 43 in IND at 12Z to 64 by 18Z. Very strong moisture advection occurring.

Type 1: 4/3/74 @ 18Z



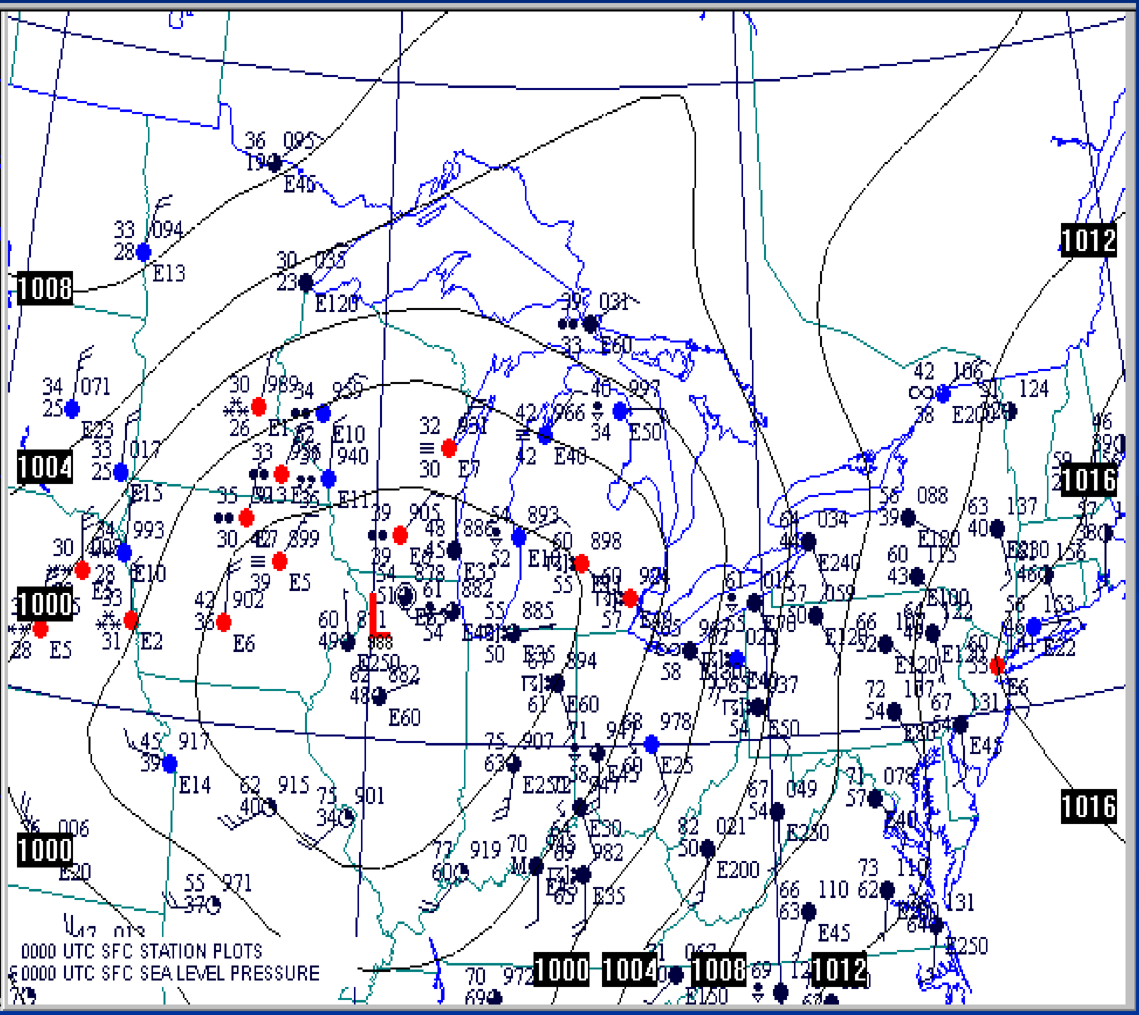
- Plot of isodrosotherms indicates how quickly moisture is increasing at the surface… dew points have jumped into the lower 50s across far southern lower MI and into the 60s across central IN.

Type 1: 4/3/74 @ 18Z



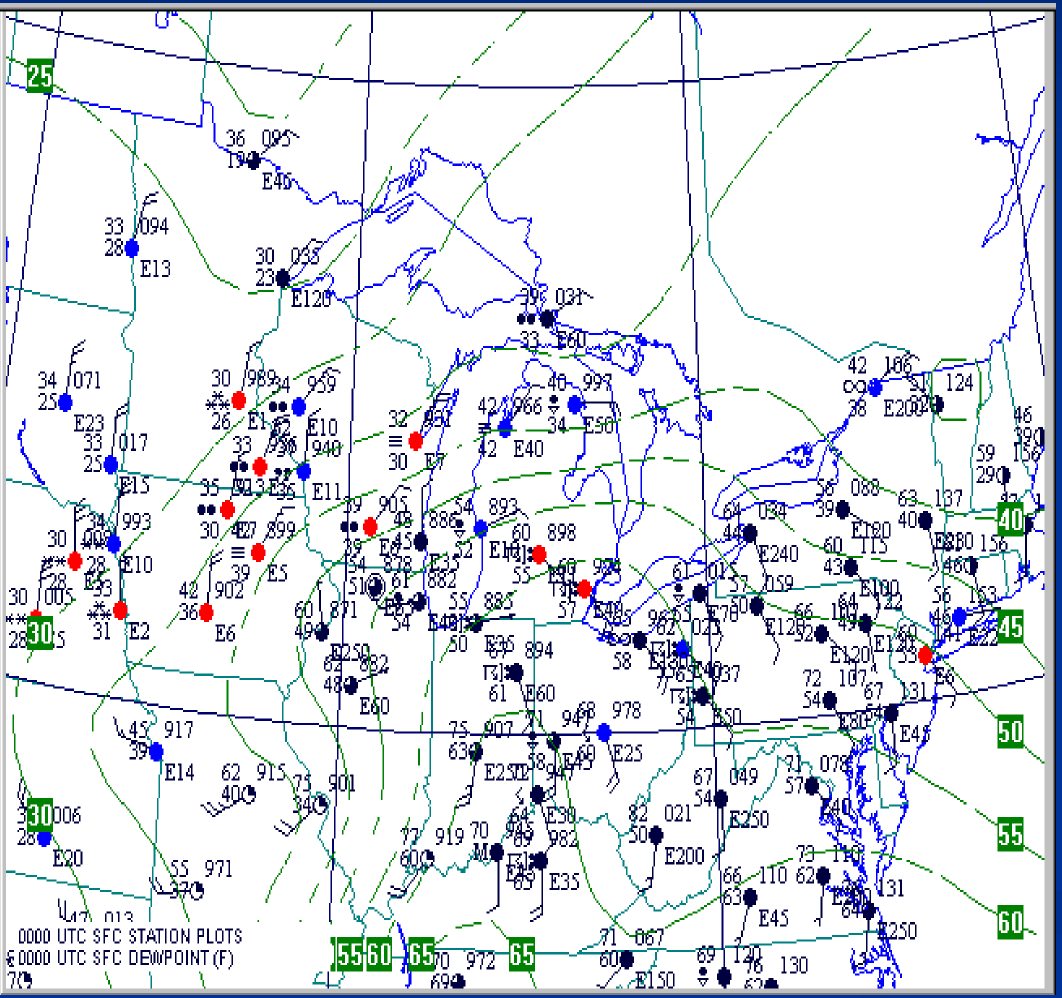
- Theta E Plot also indicates all the moisture which is increasing across the OH valley and advecting into our region in strong SE to S flow.

Type 1: 4/4/74 @ 00Z



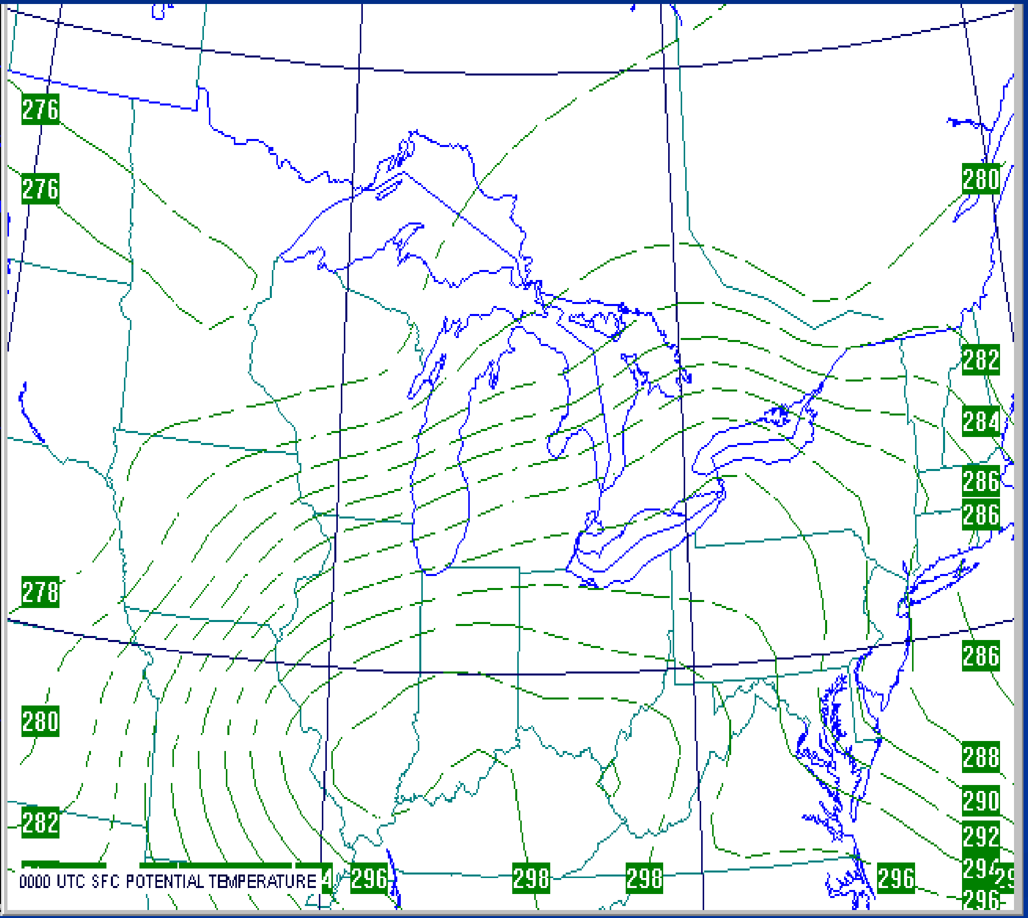
- Warm front near MKG to GRR to DTW by 00Z
- Strong sfc low over western IL
- Based on the low level wind fields and what we know about the 250 jet… imagine an environment with tremendous speed and directional shear!!!

Type 1: 4/4/74 @ 00Z



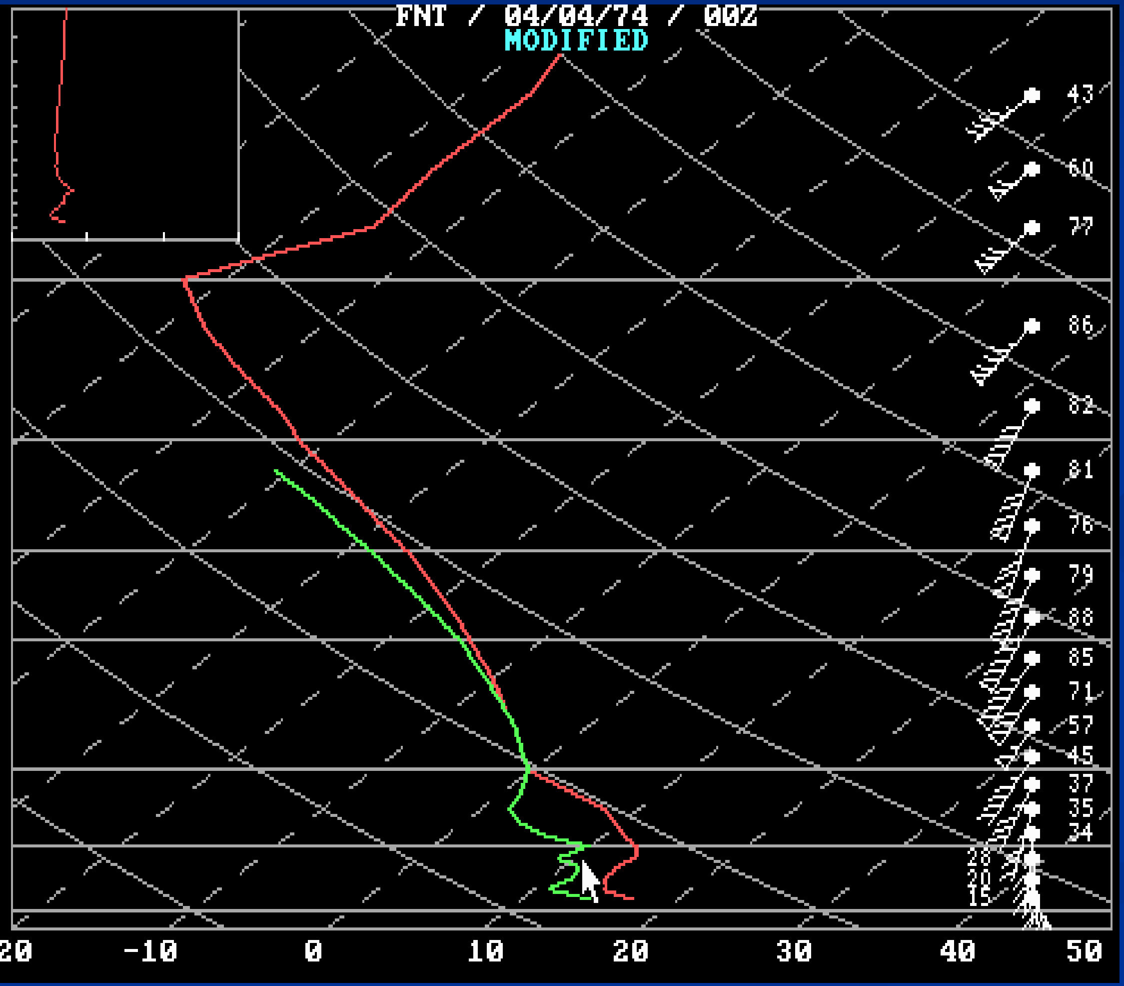
- Dew points have risen into the upper 50s across SE lower MI by 00Z and lower 60s into north IN

Type 1: 4/4/74 @ 00Z



- Theta E chart also indicates continued increase in moisture across southern lower MI, IN & OH.

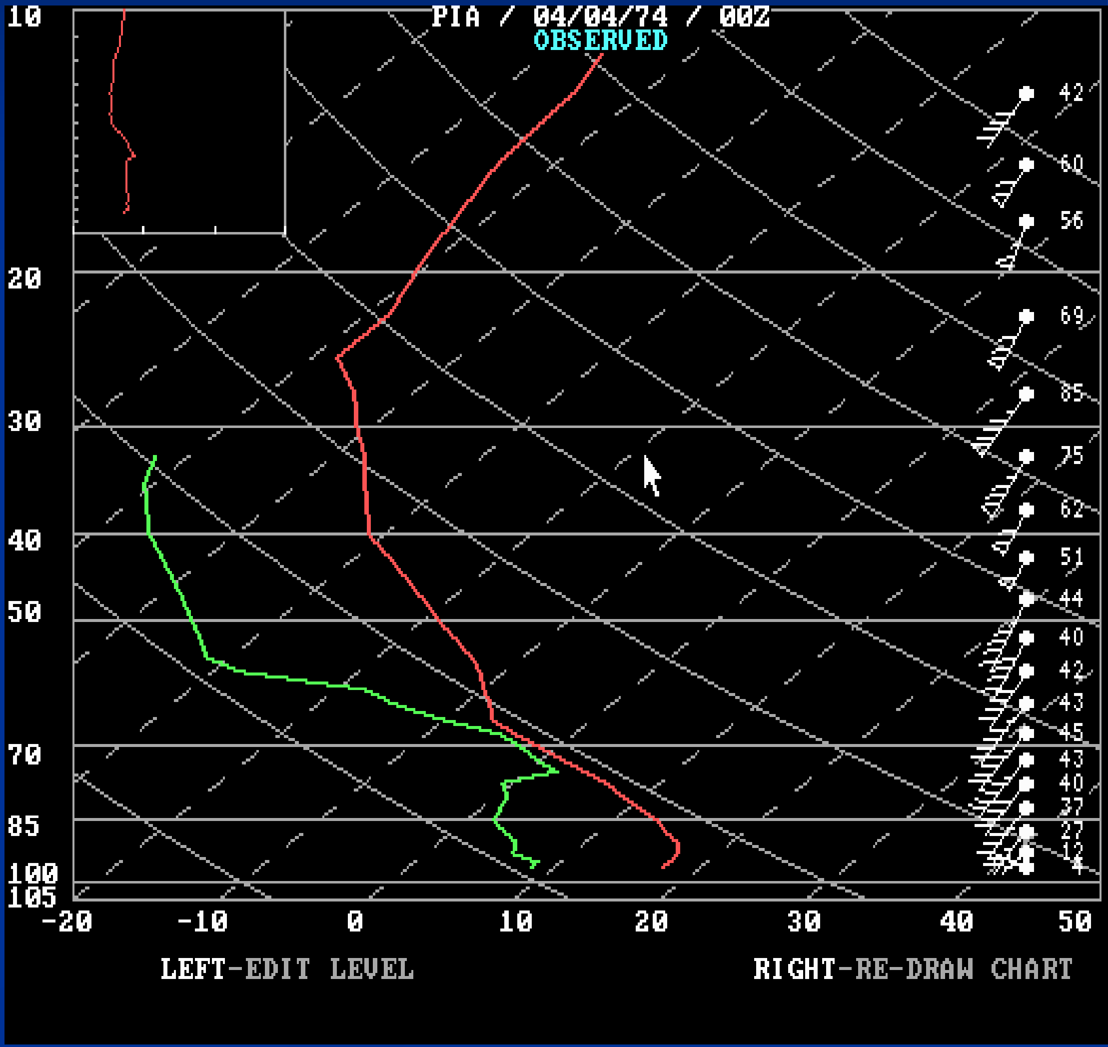
Type 1: 4/4/74 @ 00Z FNT Observed Sounding



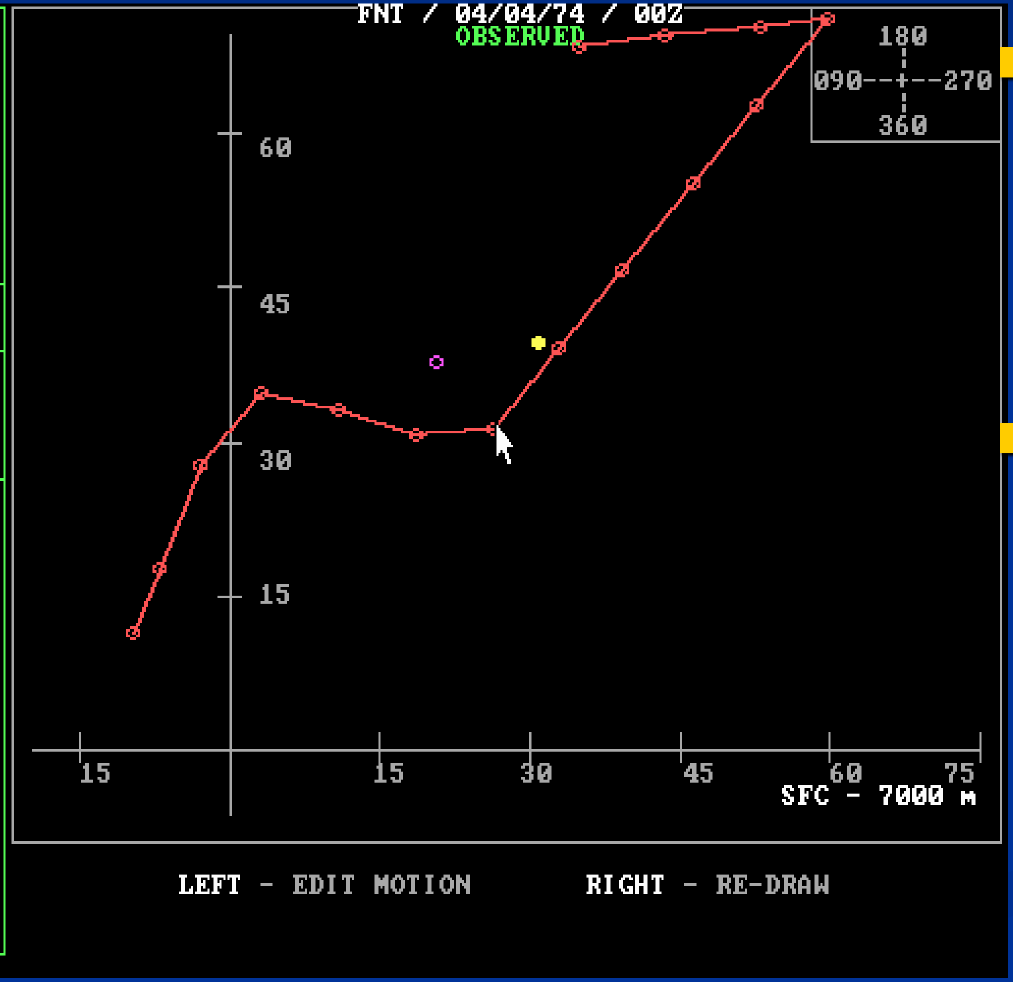
- Note that both speed and directional shear are very impressive. Some drier air at the mid levels is also noted between 700 and 850 Mb (5-10 kft).

Type 1: 4/4/74 @ 00Z PIA Observed Sounding

- Speed shear on the 00Z observed PIA sounding is very impressive.



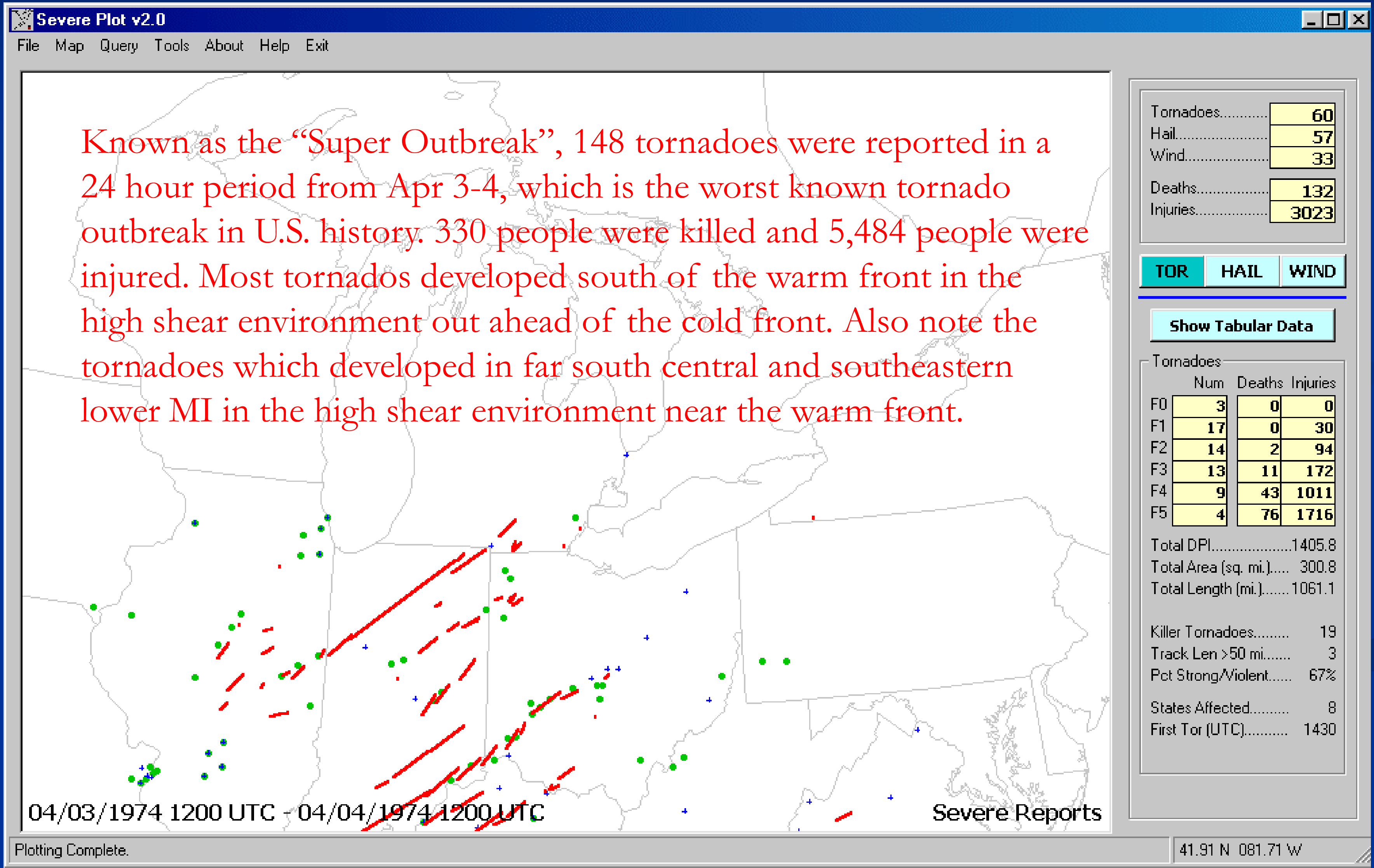
Type 1: 4/4/74 FNT @ 00Z Hodograph



- Note the length of the hodograph resulting from very strong wind fields and speed shear!
- This magnitude of speed shear is conducive to splitting supercell thunderstorm formation

Type 1: 4/3/74 Severe Wx Reports

Known as the "Super Outbreak", 148 tornadoes were reported in a 24 hour period from Apr 3-4, which is the worst known tornado outbreak in U.S. history. 330 people were killed and 5,484 people were injured. Most tornados developed south of the warm front in the high shear environment out ahead of the cold front. Also note the tornadoes which developed in far south central and southeastern lower MI in the high shear environment near the warm front.

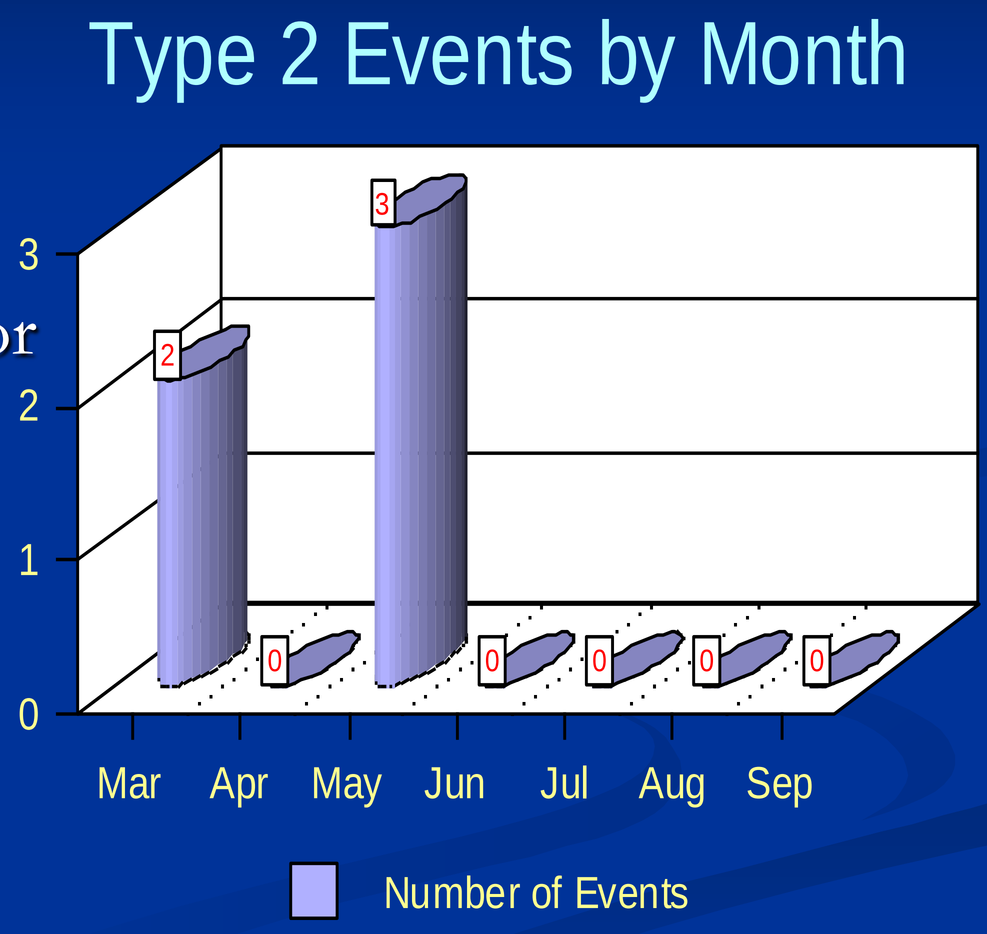


Summary Type 1 Parameters

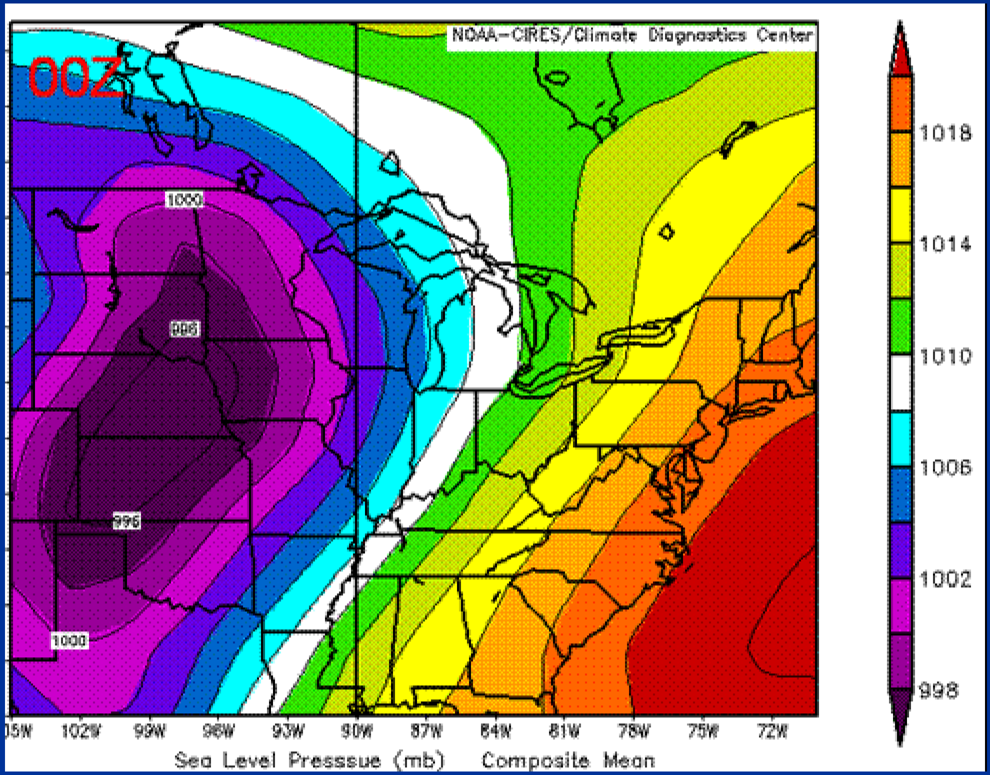
- Type 1 cases exhibit very high deep layer shear values.
- These are classic high shear, low CAPE environments.
- CIN values aren't really low, but low enough such that strong forcing can overcome them.
- 00Z soundings indicate marginal LFC heights of around 2,000 to 2,500 meters…this may be misleading since they can be a little lower locally.
- Modified soundings show significant 0-1 km SRH available in the storm environment (greater than 100 m^2/s^2).

Type 2 Events

- 5 events
- All occurred in March or May



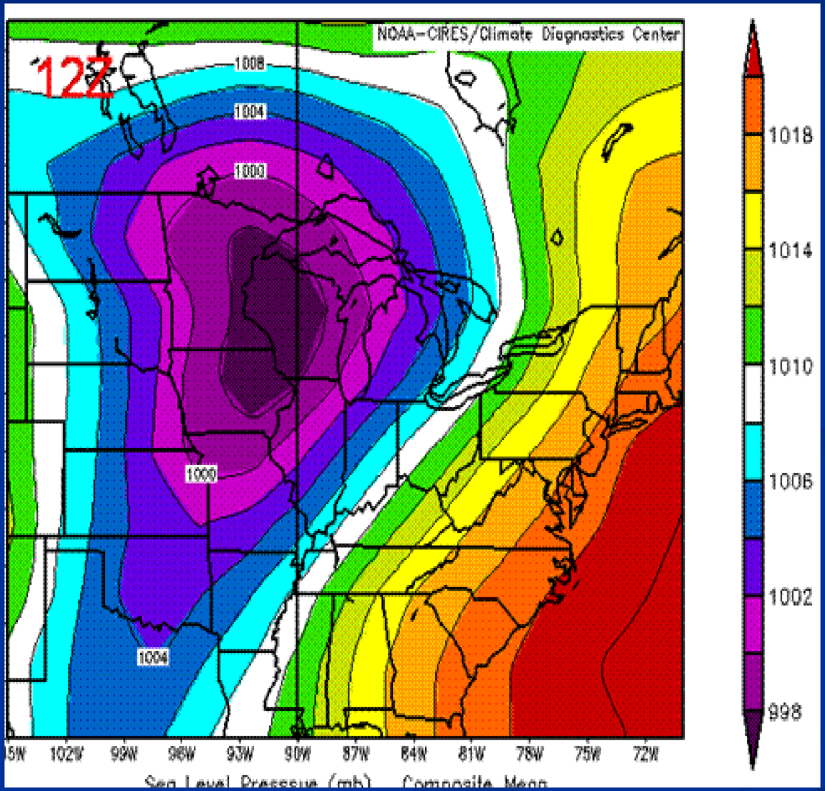
MSLP – Type 2



- Low takes a more westerly track than in Type 1
- Once again, gulf moisture is abundant

MSLP – Type 2

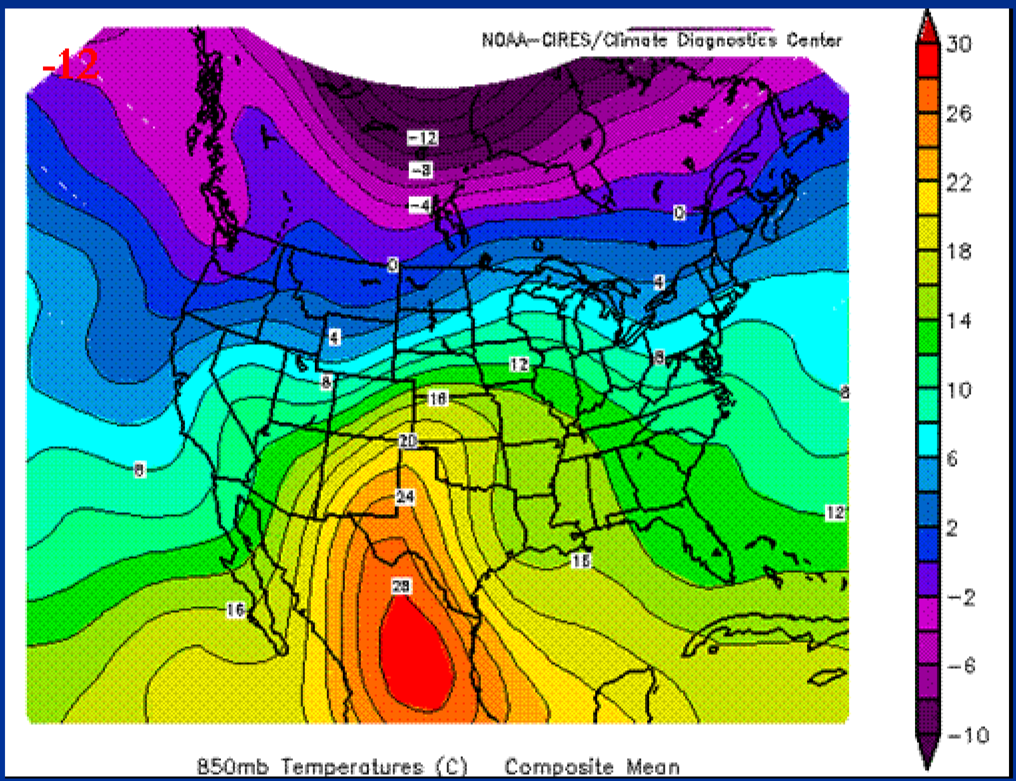
- Position of warm front is very significant. It has already lifted north across northern lower MI by 12Z. This is one of the most fundamental differences between Type 1 and Type 2 events.



Surface Fields – Type 2 Cases

- At 1800 UTC Type 2 cases typically had surface temperatures in the 60s F. Range was from the mid 50s to the mid 70s across southern lower Michigan.
- Surface dewpoints were typically in the 50s with a range from the lower 50s to the upper 50s.
- Dewpoint depressions across southern lower Michigan were generally in the 8-11 F range.

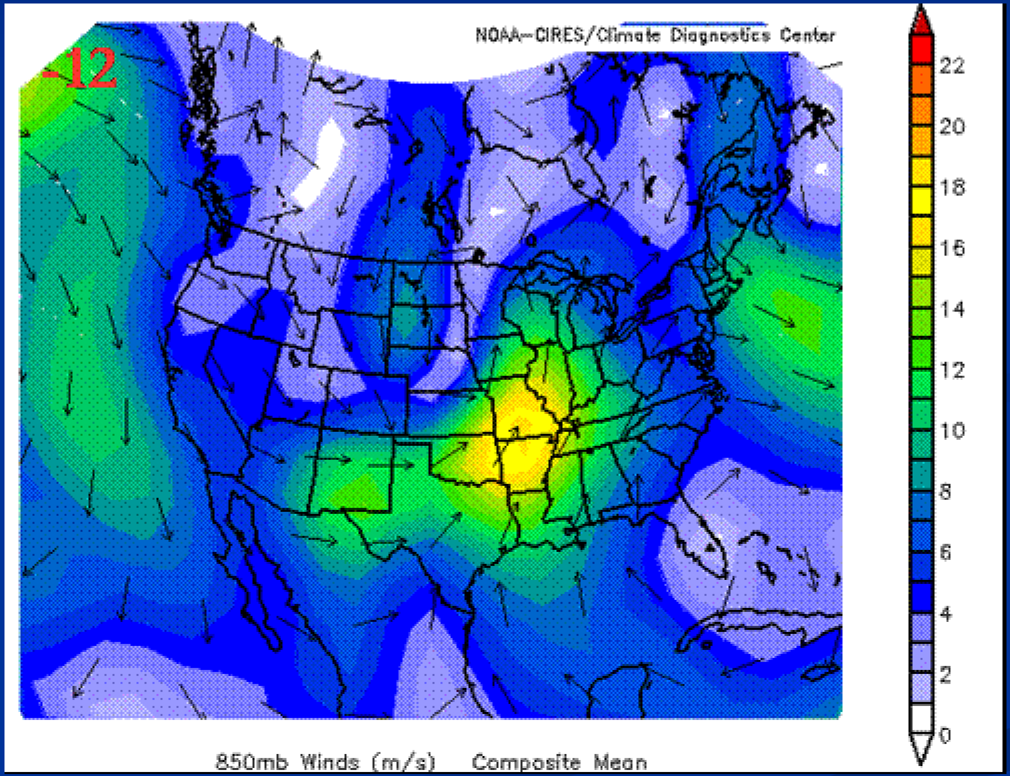
850 MB T – Type 2



- 850 MB T pattern is similar to those of Type 1… +10 to +12 into the OH valley and cold pocket into the northern Plains states.

850 MB Winds

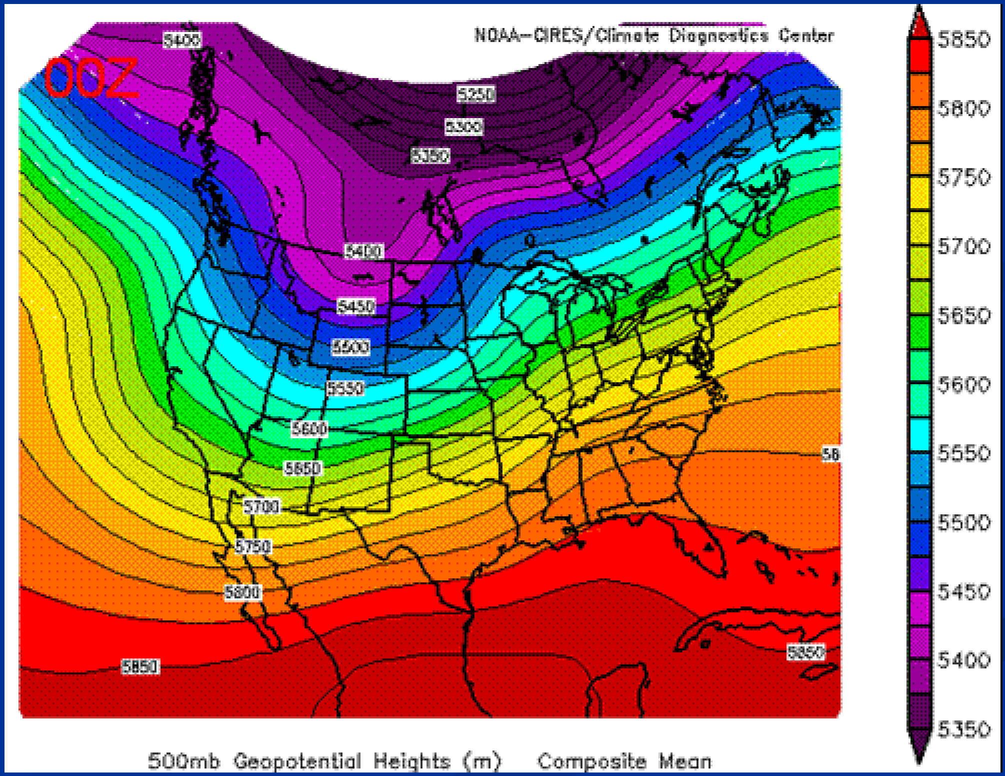
We have an 850 wind structure quite similar to type one, where the core of the strongest winds strengthens and lifts northeast. In fact the 850 mb winds are even stronger across southern lower MI, reaching speeds of around 50 to 55 knots.



500 MB Heights

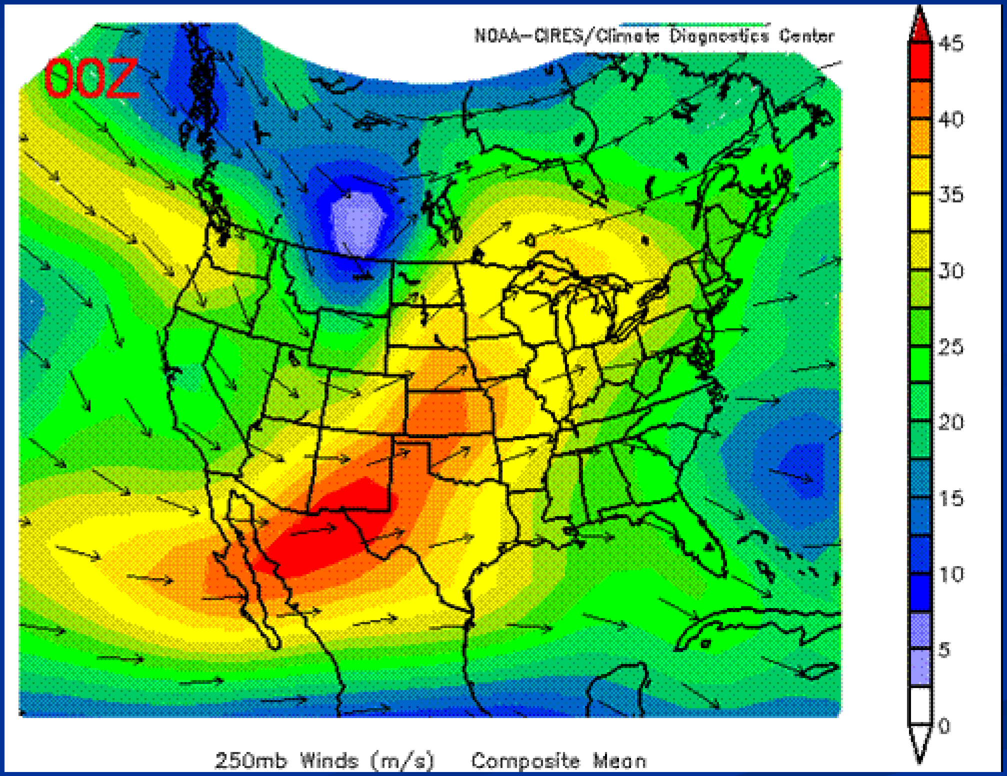
Here we see a weak longwave ridge over the eastern U.S. and upper trough over the northern Rockies. The upper trough axis translates east southeast rather quickly causing the upper ridge to build over the East Coast and Western Atlantic.

However, it is important to note that the 500 pattern was not as amplified as in the type one composite (slide 16).

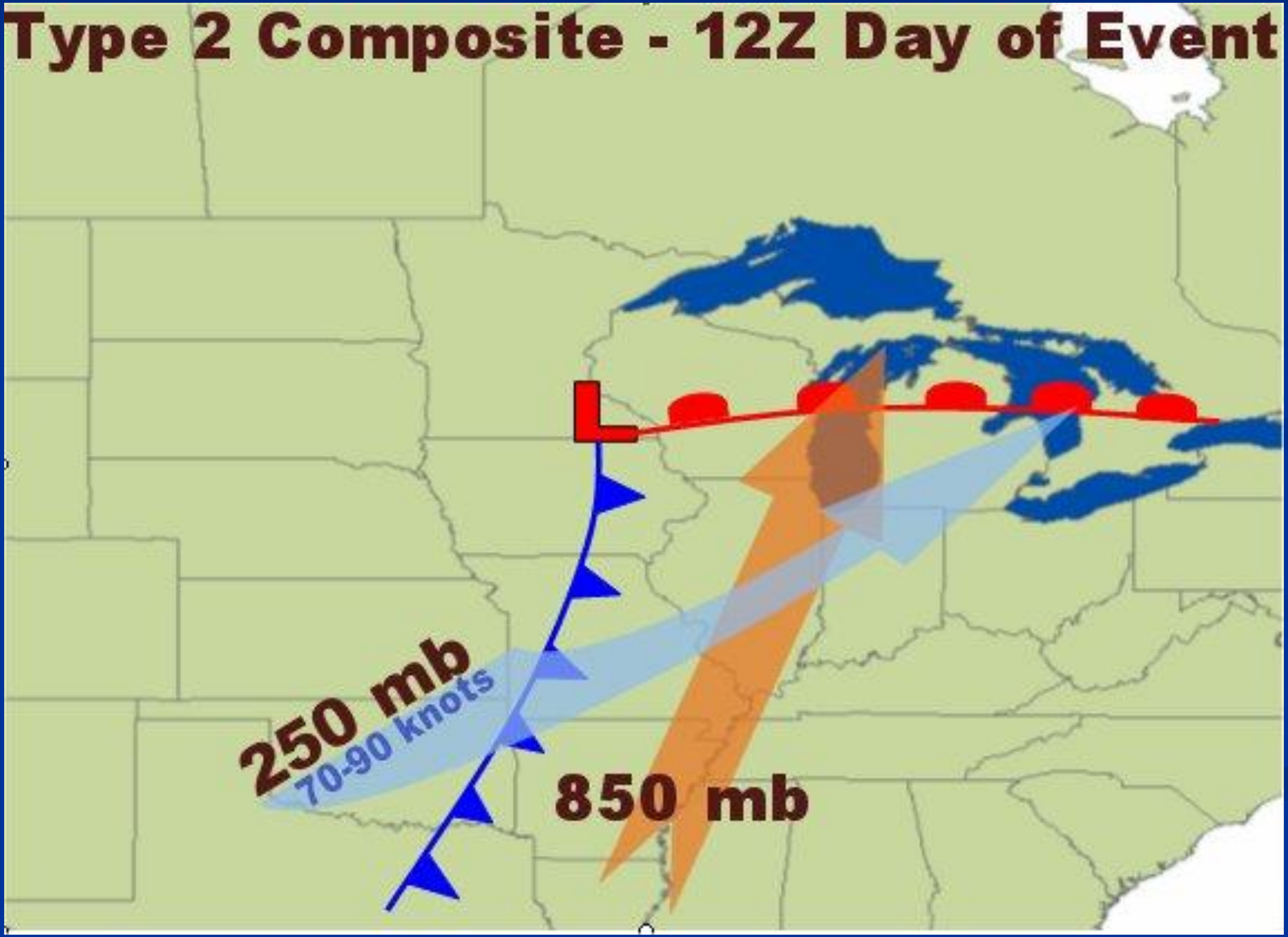


250 MB Winds – Type 2

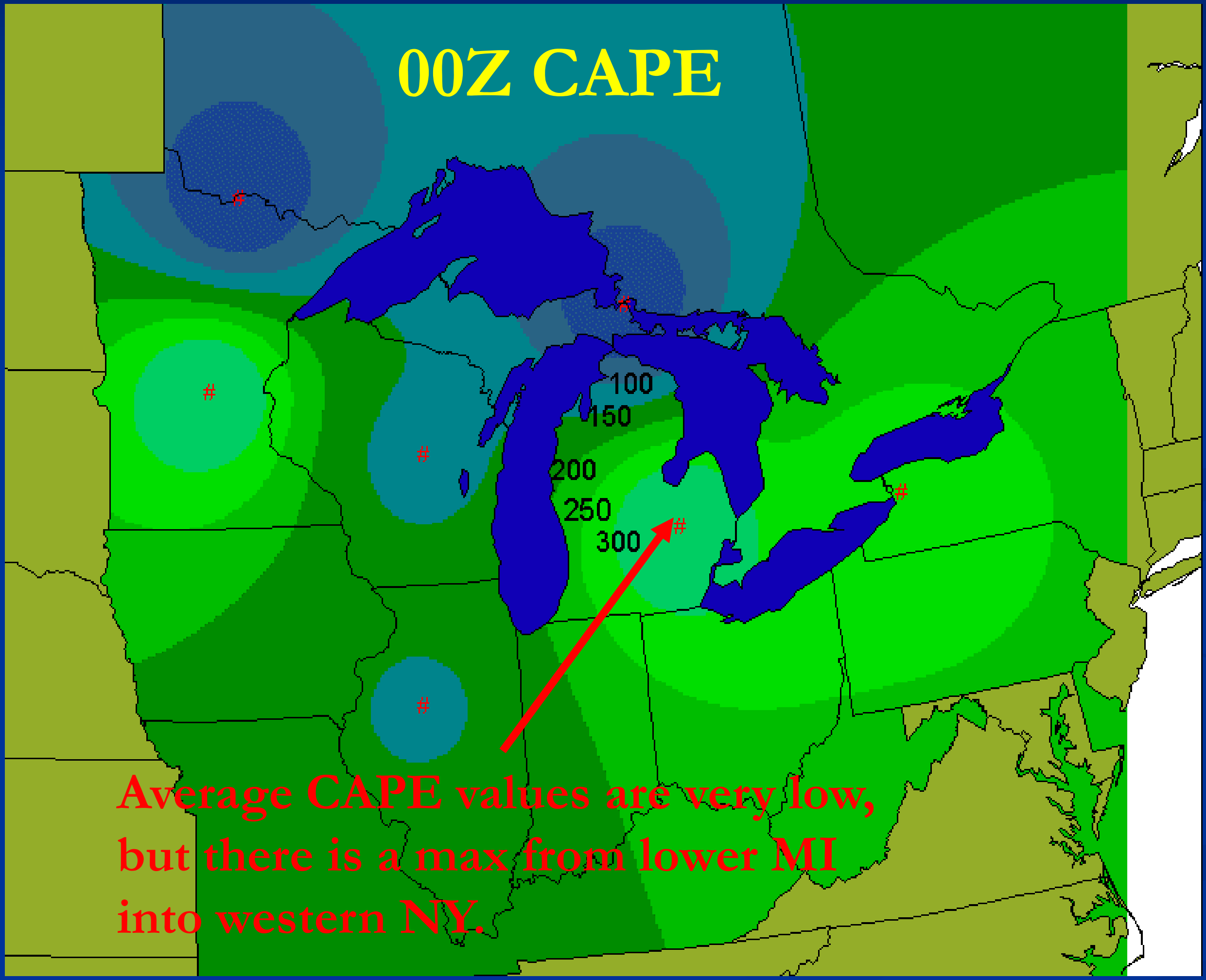
- Significantly weaker jet than in Type 1.
- The jet core has a similar evolution from the southwestern U.S. northeast through the Plains into the Great Lakes region.



Type 2 - Surface and Upper Air Composite



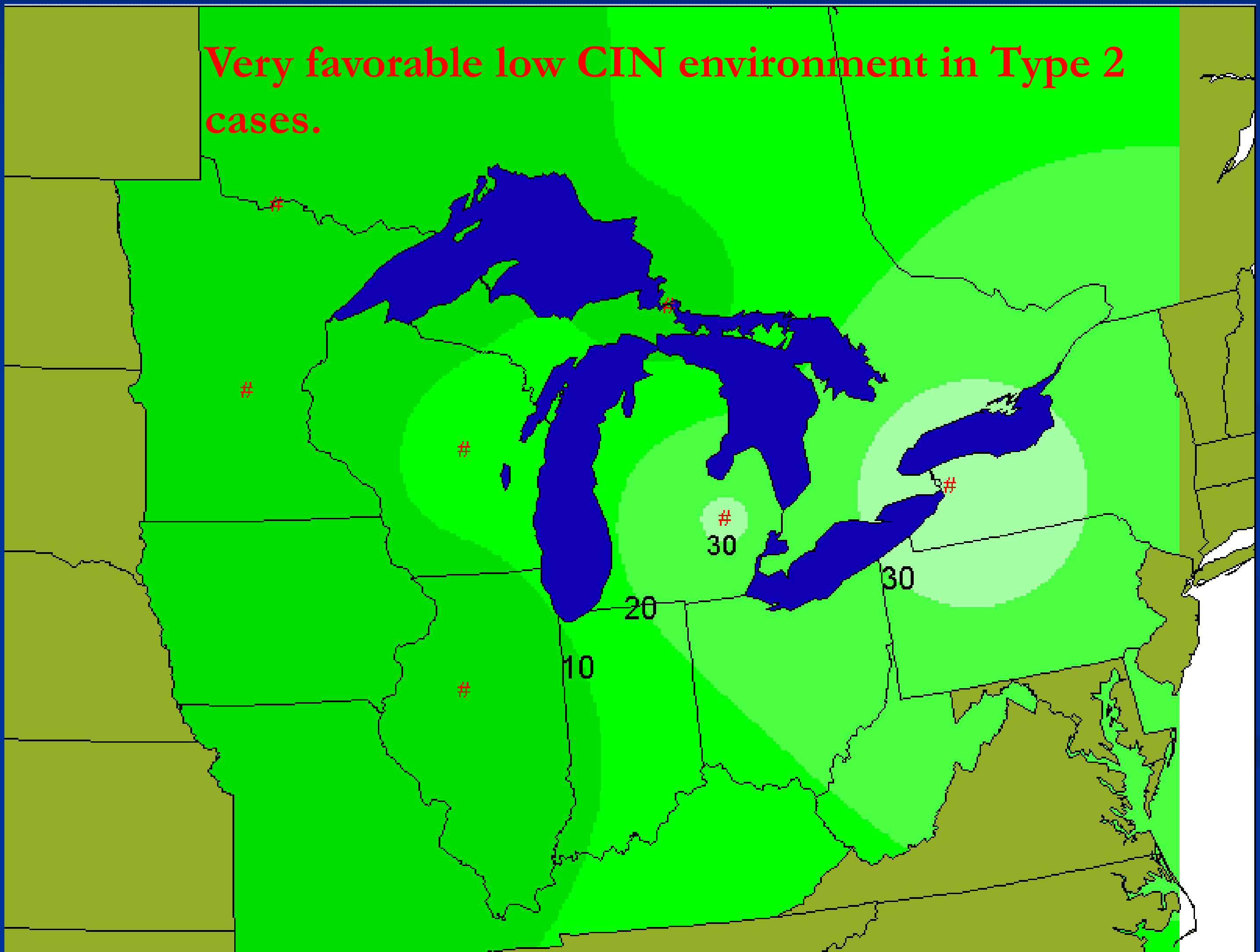
Type 2 – CAPE (Pmax)



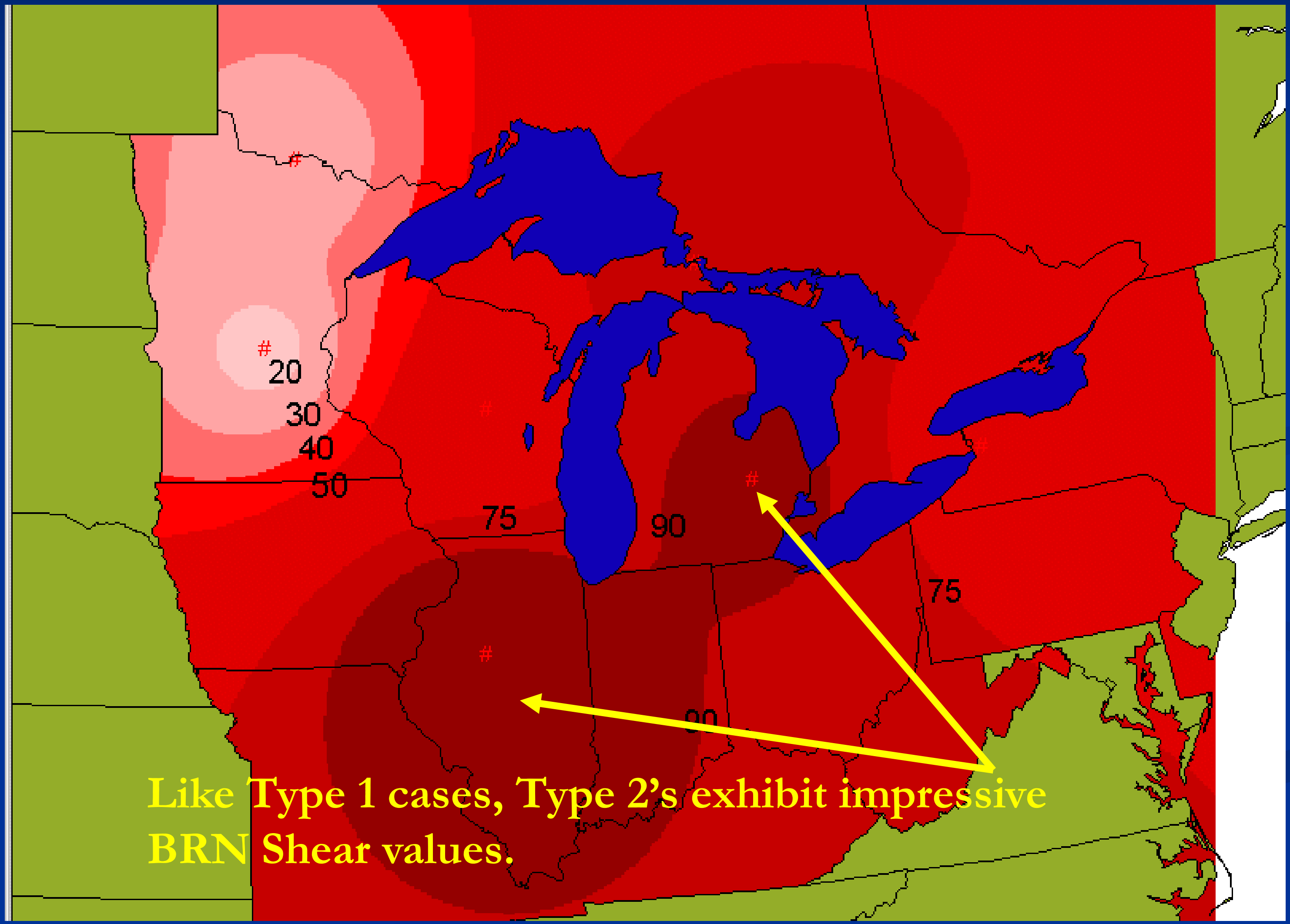
On average CAPE values were only 250-300 J/kg across lower MI at 00Z.

However, soundings modified using representative surface data from around the time of the tornado events yielded CAPE (Pmax) values around **580 J/kg**.

Type 2 – 00Z CIN

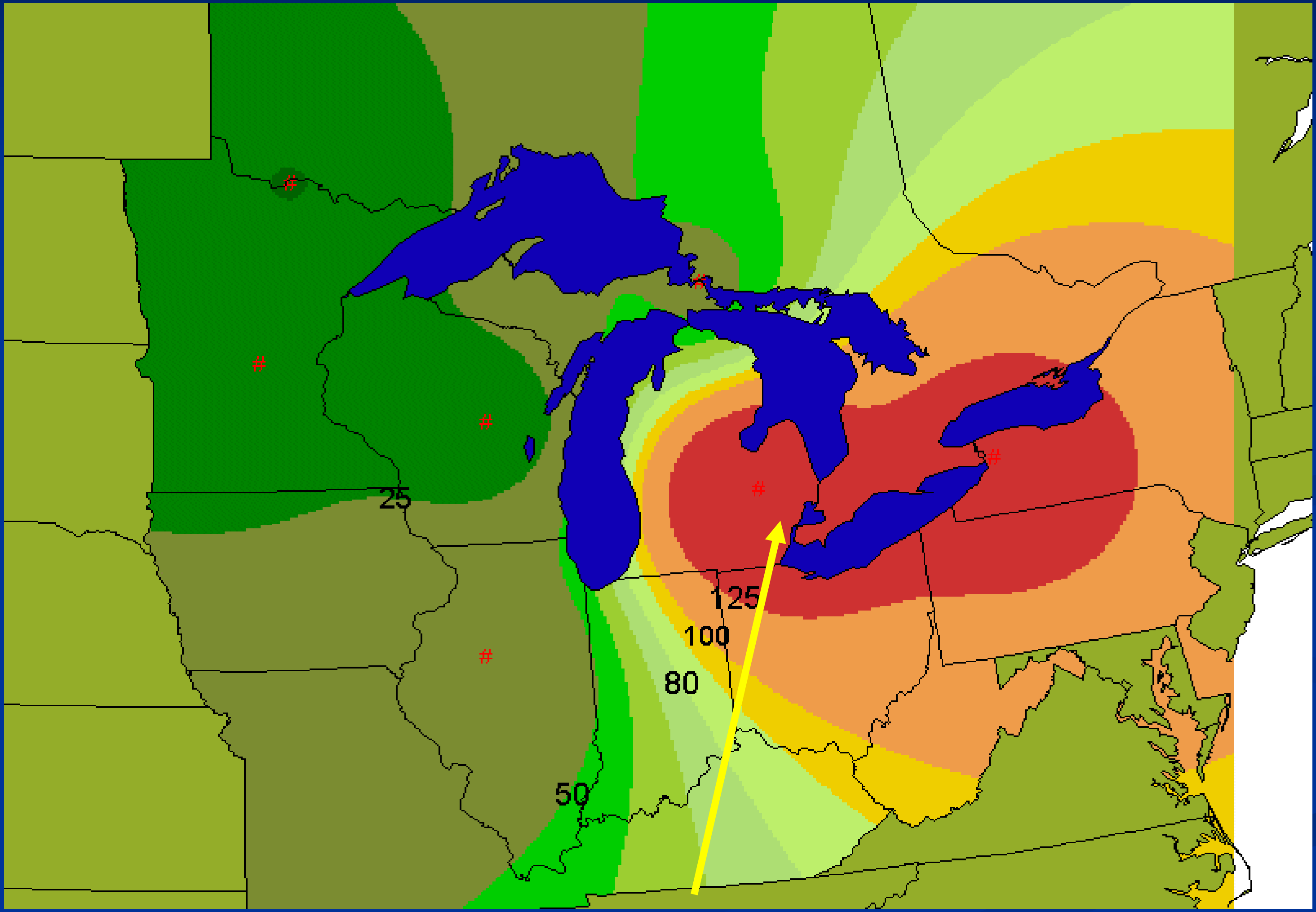


Type 2 – 00Z BRN Shear



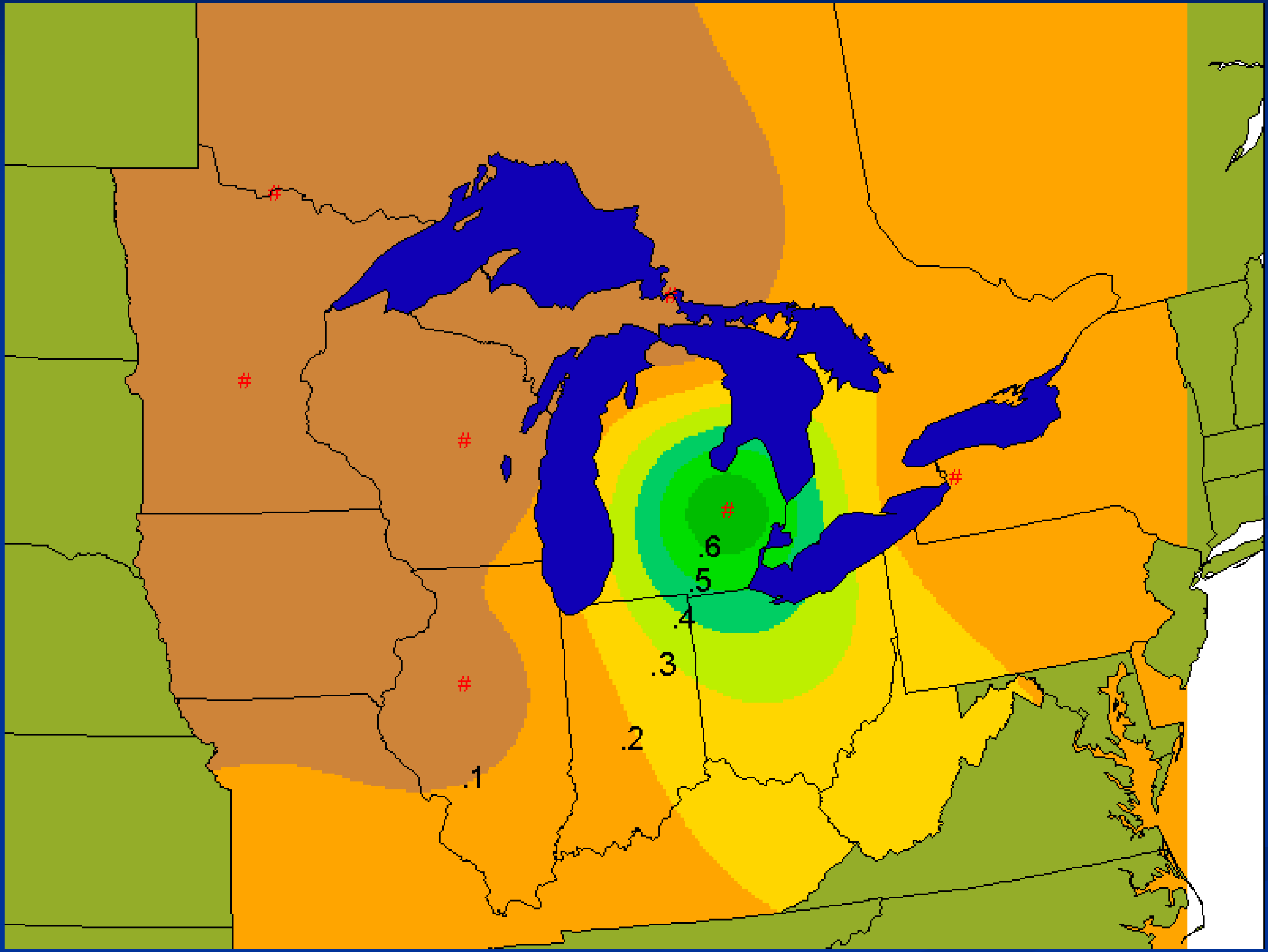
Like Type 1 cases, Type 2's exhibit impressive BRN Shear values.

Type 2 – 00Z 0-3 km SRH



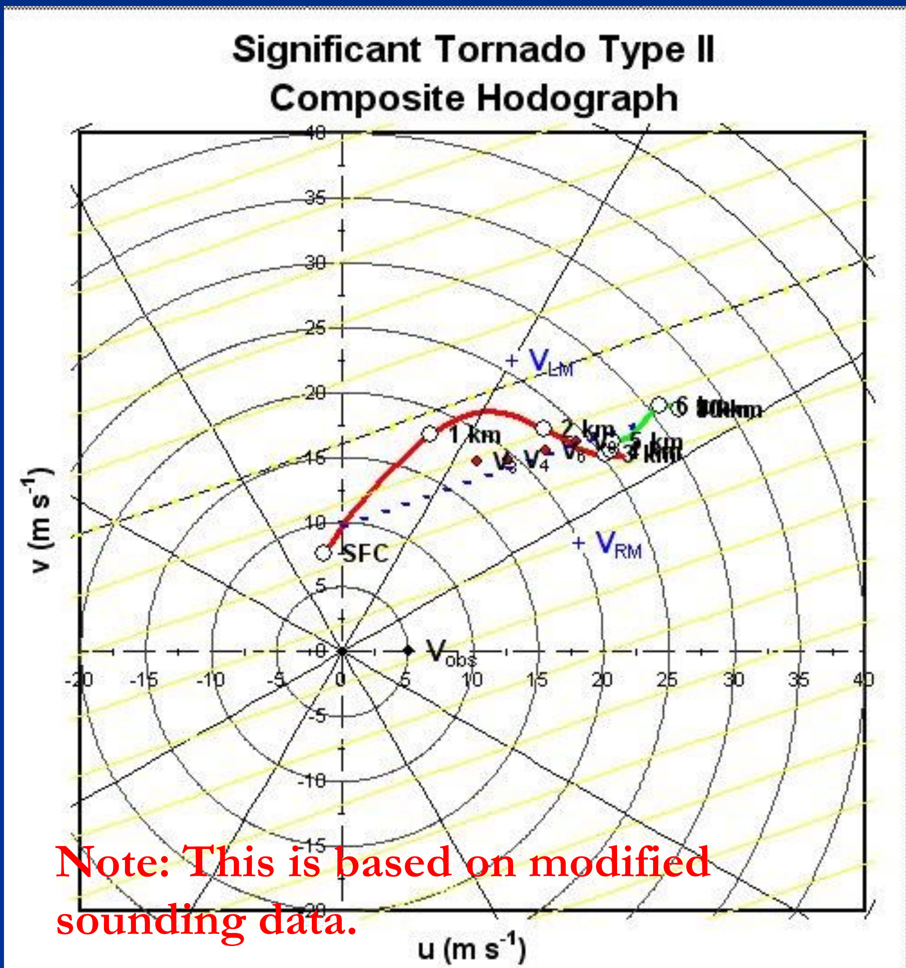
Again a pretty good core of 0-3 km SRH. For Type 2's this is shifted farther east than in Type 1 cases.

Type 2 – 00Z EHI



EHI values are quite a bit larger than they are for Type 1 cases.

Type 2 - Composite Hodograph

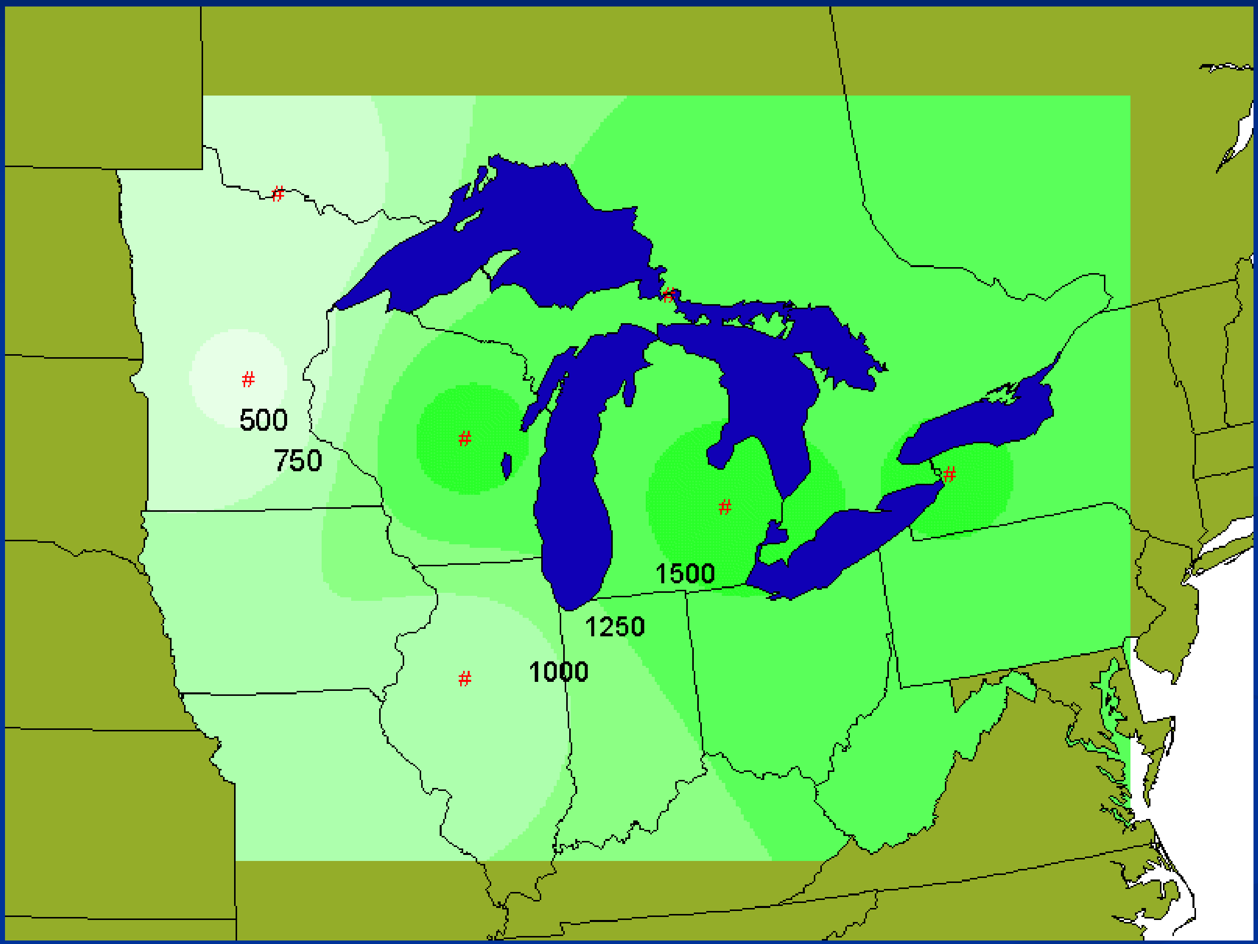


Note: This is based on modified sounding data.

Used wind from representative surface observation near the time of the tornado events to modify upper air sounding.

0-1 km SRH	**138 m2/s2**
0-3 km SRH	254 m2/s2
0-6 km Shear	27 m/s

Type 2 – 00Z LFC Heights (m)

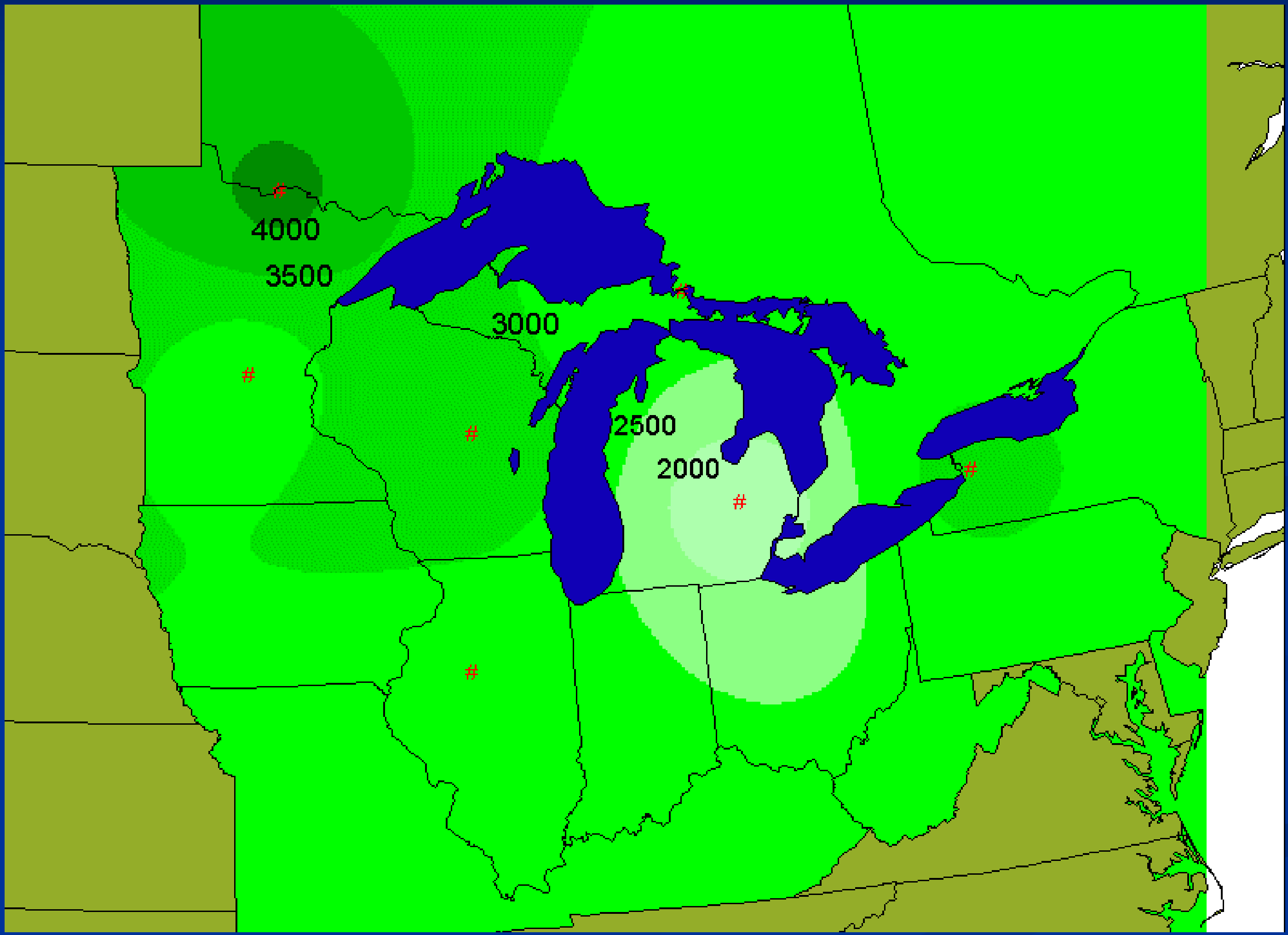


On average 00Z LFC values were 1250-1500 m across lower Michigan.

Soundings modified using representative surface data from around the time of the tornado events yielded LFC heights around **1200 m**

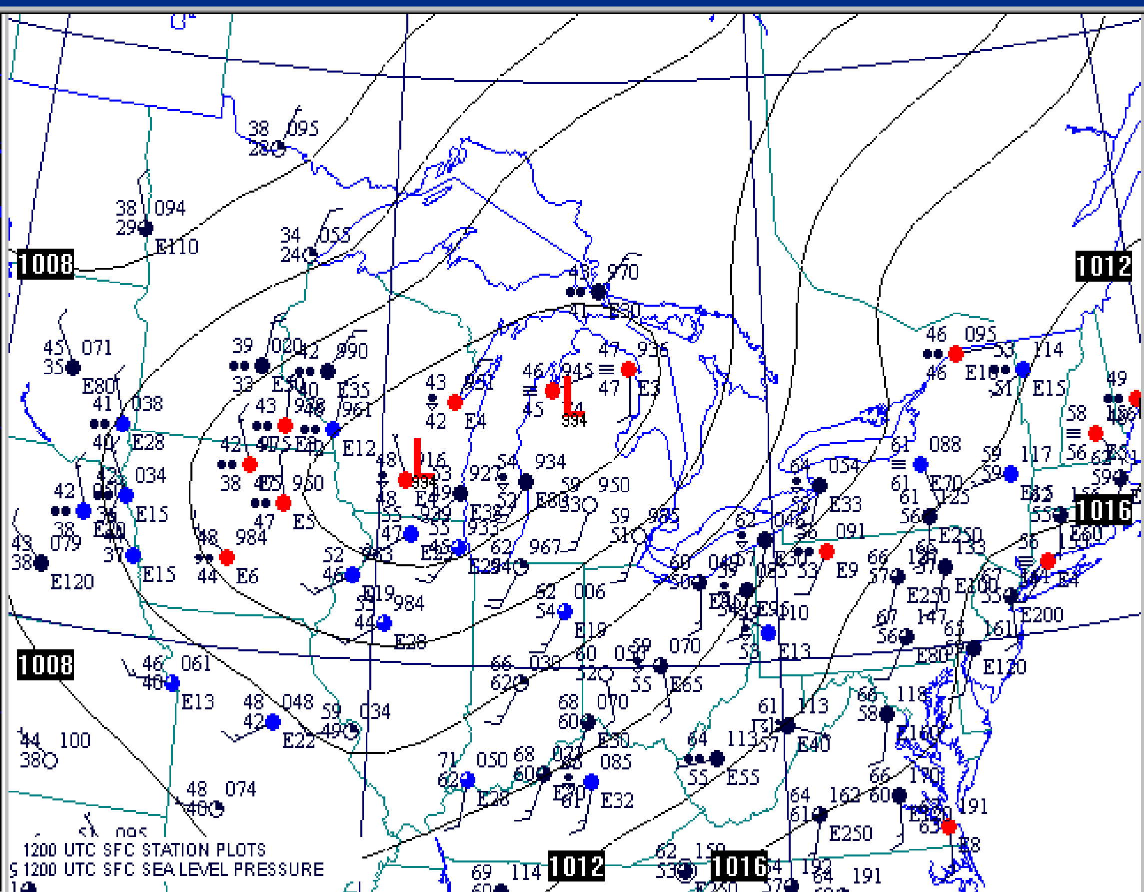
Type 2 cases also exhibit the most favorable LFC environments. Type 2's tend to exhibit low LFC heights over a large region.

Type 2 – 00Z LCL (ft)



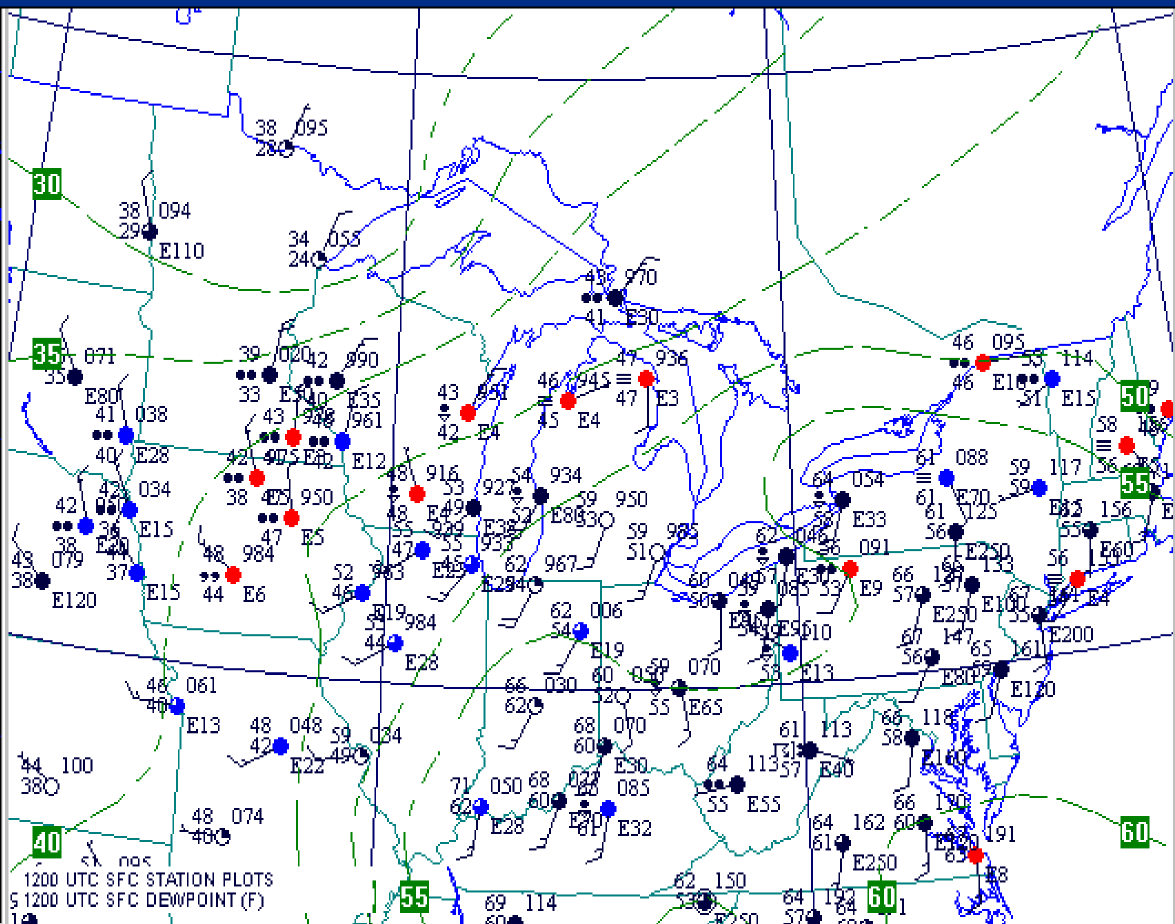
As one would expect LCL heights are also quite low.

“Classic” Type 2 Event: 5/2/83 @ 12Z



- Low pressure centered near MKE with warm front across northern lower MI
- Cold front into western IL

Type 2: 5/2/83 @ 12Z

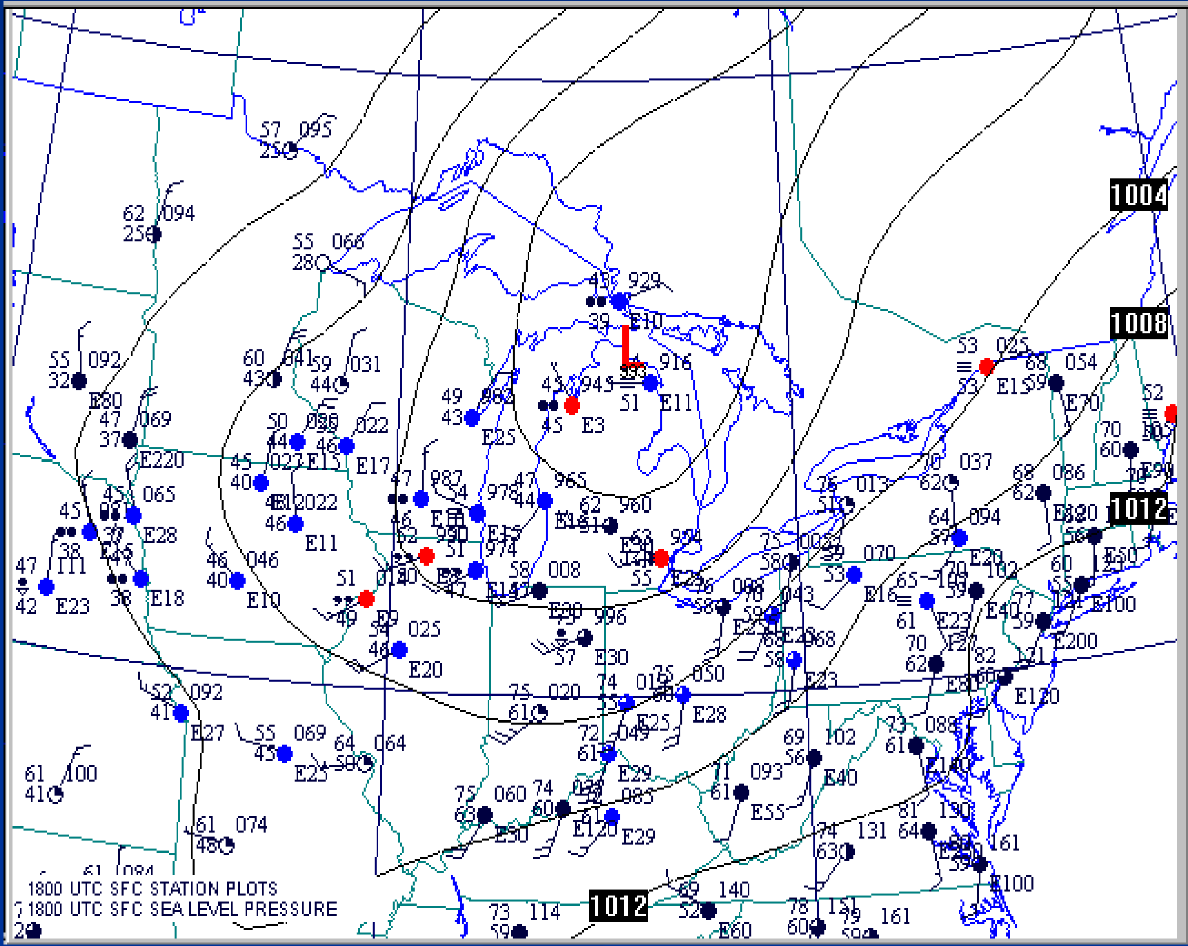


- Dew points into the 50s across southern lower MI and in the lower 60s into north central IN. Generally starting out with higher moisture at the sfc than in Type 1 cases since the warm front is already north of our area at 12Z. This also correlates to lower LCL heights in type 2 cases.

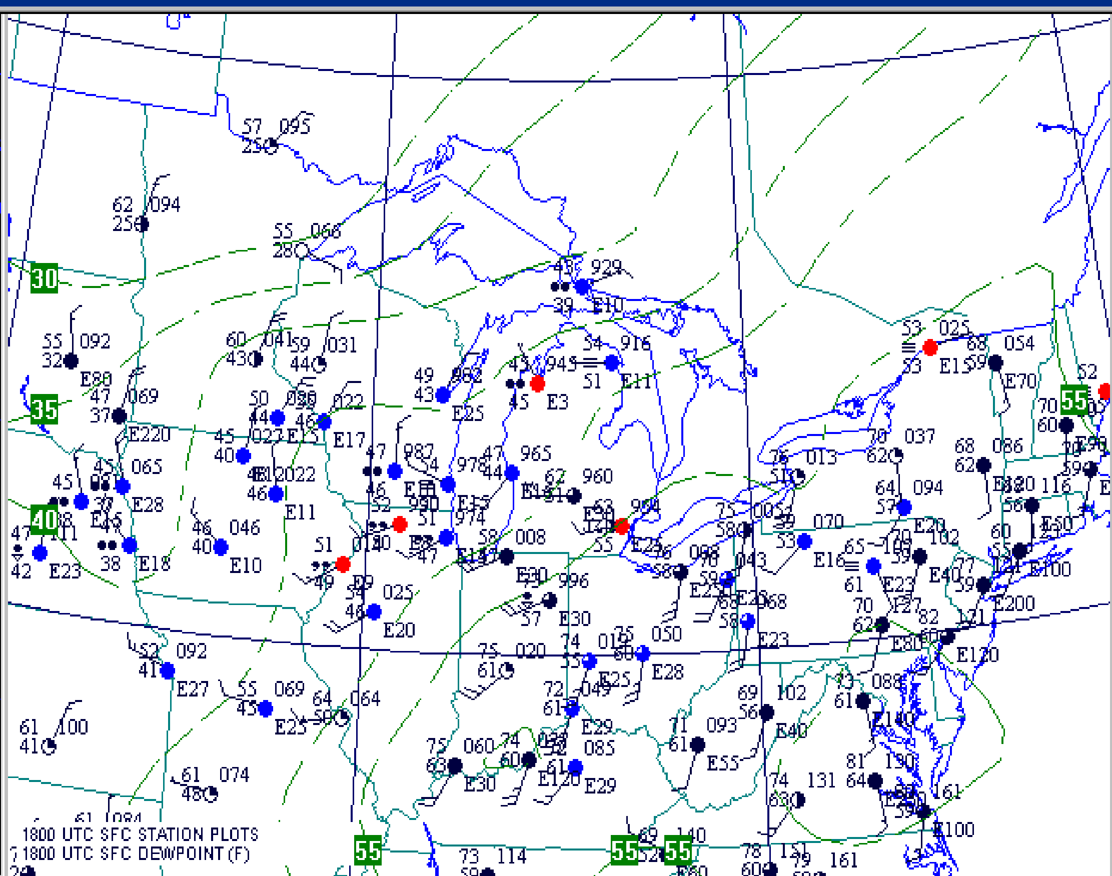
5/2/83 @ 18Z

- Low near Pellston with cold front SSW through MBL down to ORD

- In this particular case dew points haven't really had much of an increase across our area, since flow is already veering to the SW just ahead of the cold front. Theta e advection in this case also is not as strong as in typical Type 1 cases. This is because flow off the gulf was not quite as strong and the strongest low level moisture advection is displaced farther east.

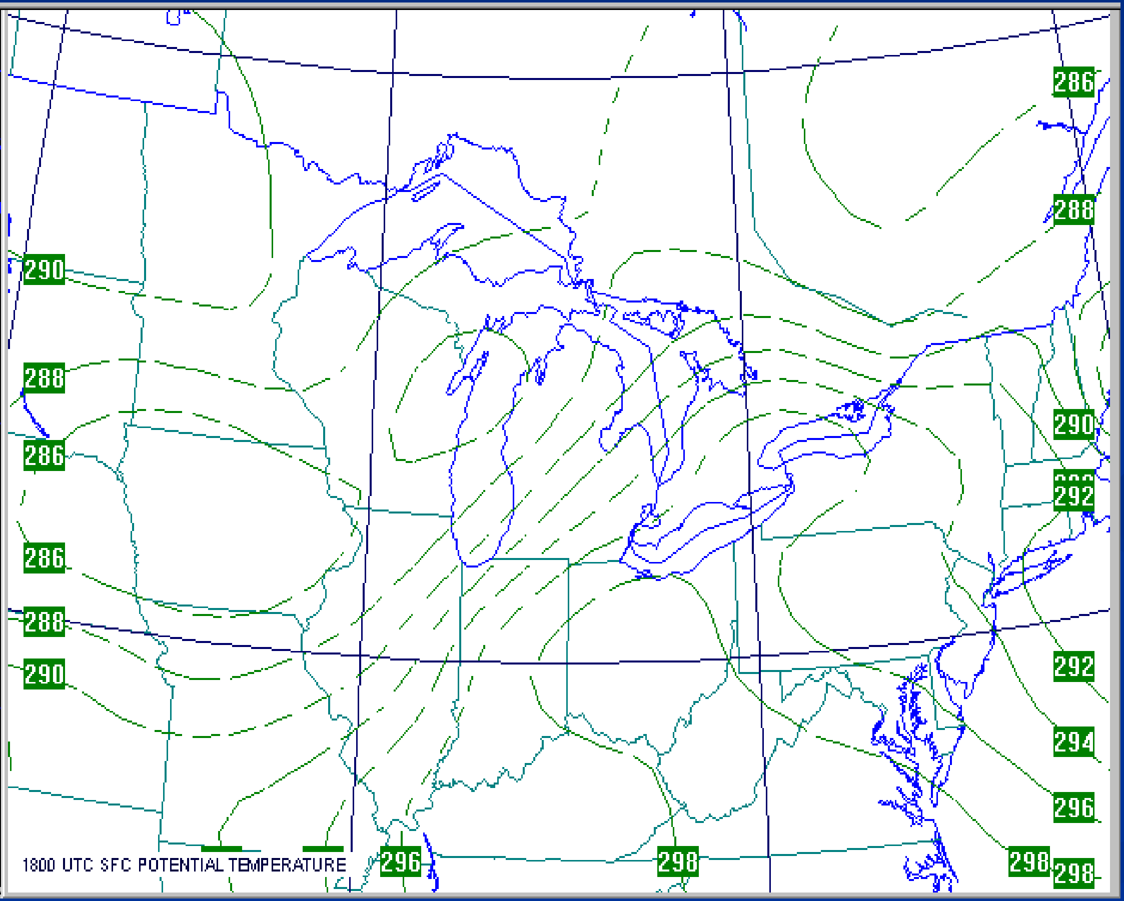


5/2/83 @ 18Z



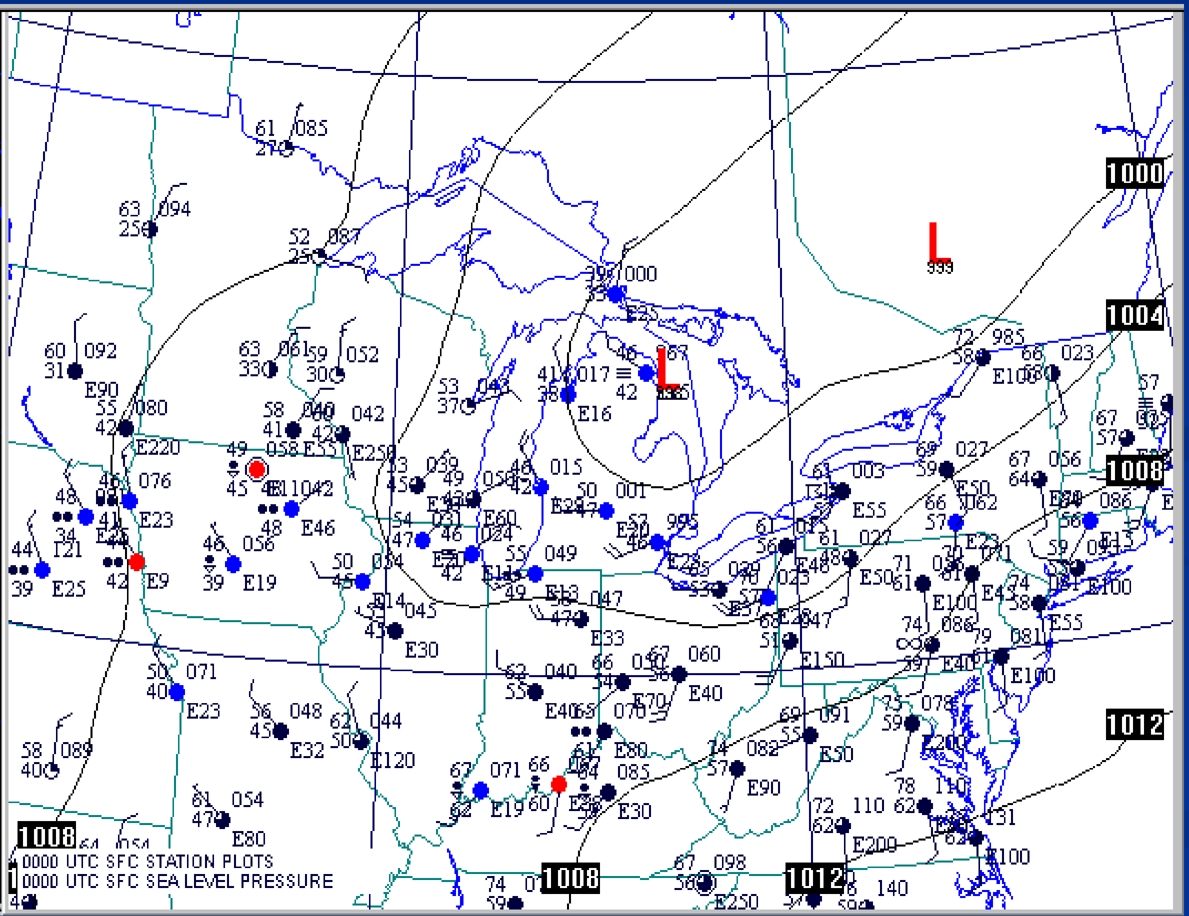
- In this particular case dew points haven't really had much of an increase across our area, since flow is already veering to the SW just ahead of the cold front.

5/2/83 @ 18Z



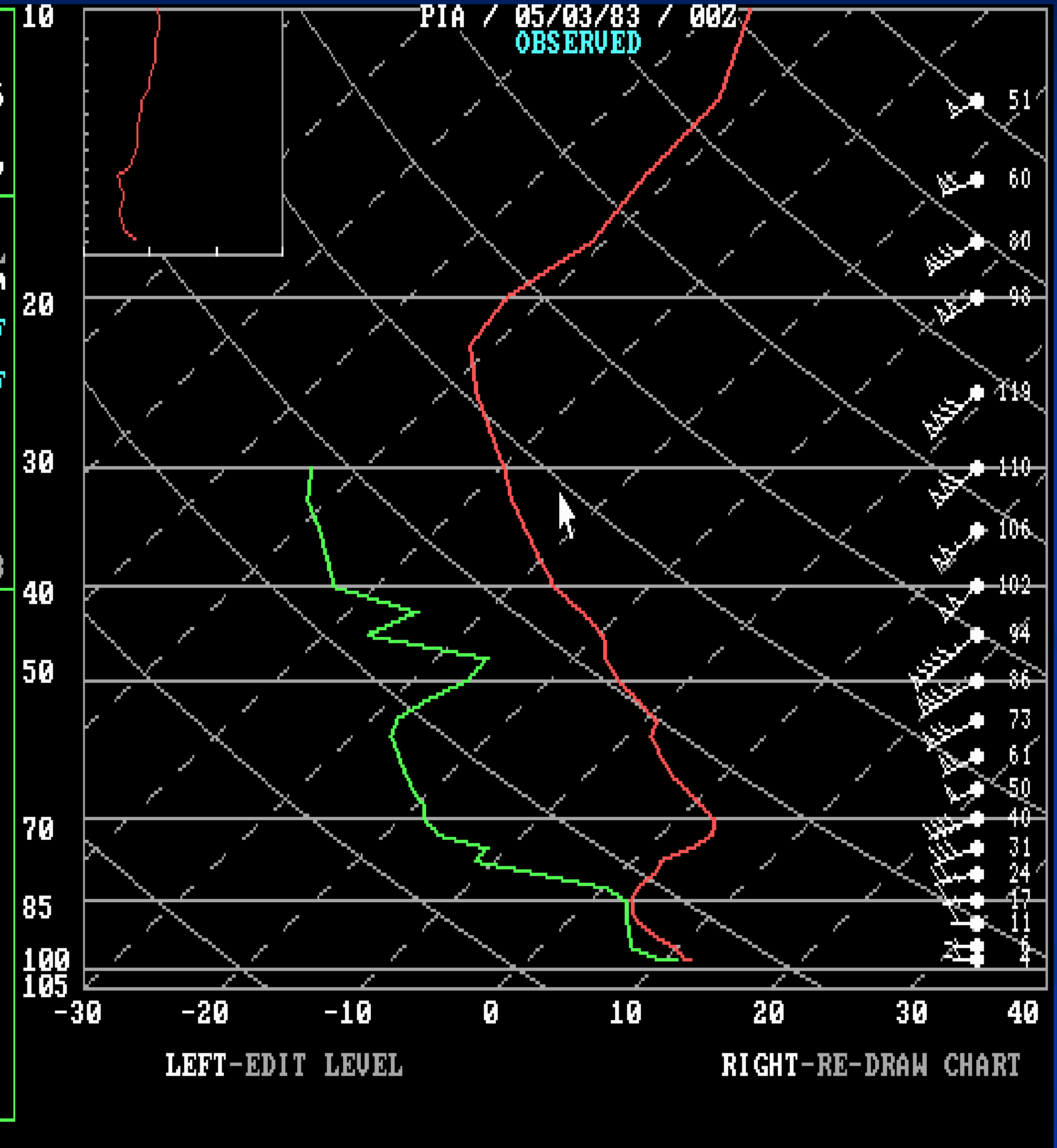
- Theta e advection in this case also is not as strong as in typical Type 1 cases. This is because flow off the gulf was not quite as strong, and the strongest low level moisture advection is displaced farther to our southeast.

5/3/83 at 00Z



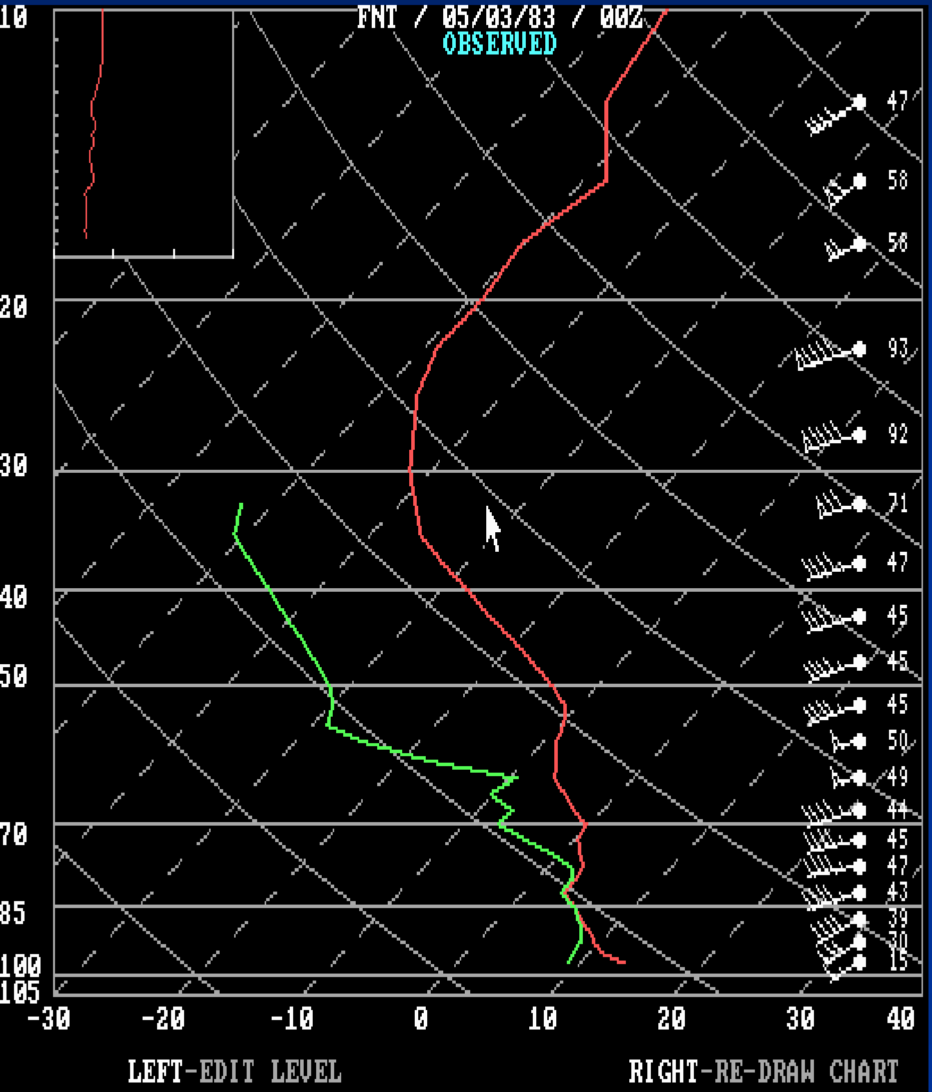
- Sfc low moves farther east into Ontario Canada and pulls cold front east through western lower MI.

5/3/83 @ 00Z - PIA



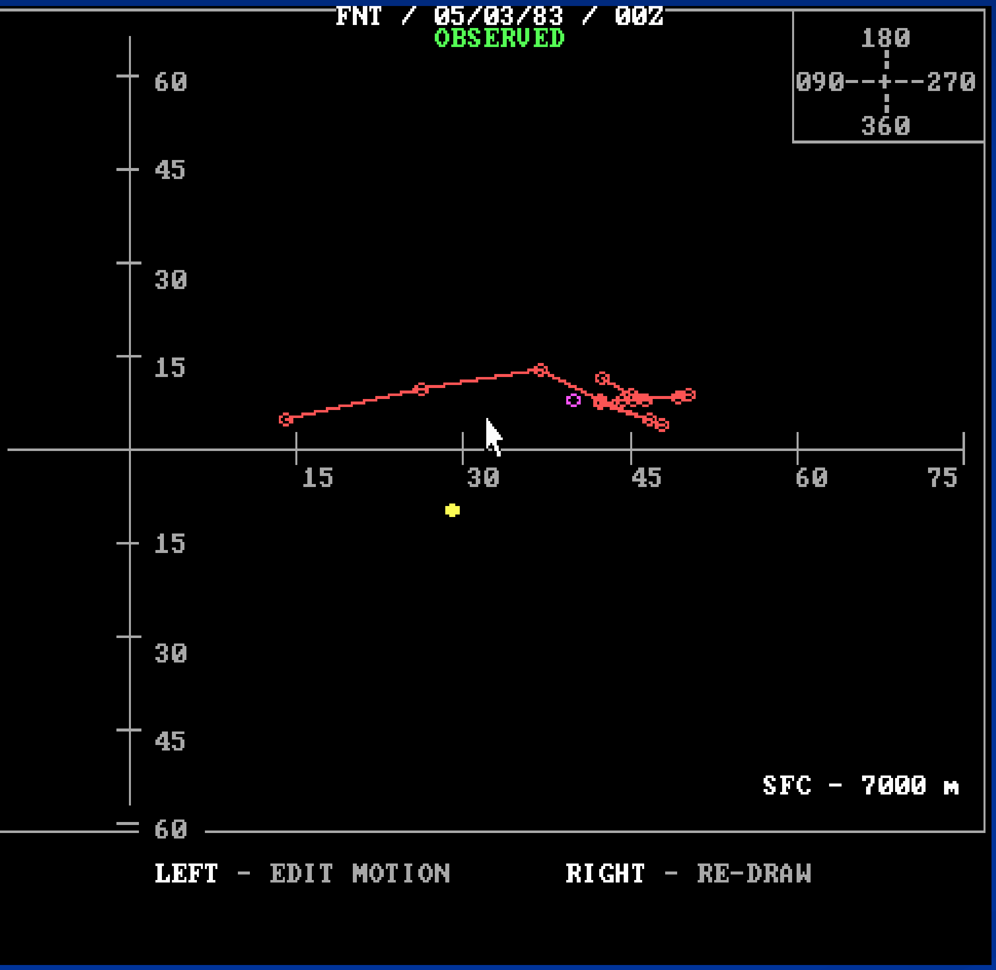
- Cold front is already through PIA at 00Z

5/3/83 @ 00Z - FNT



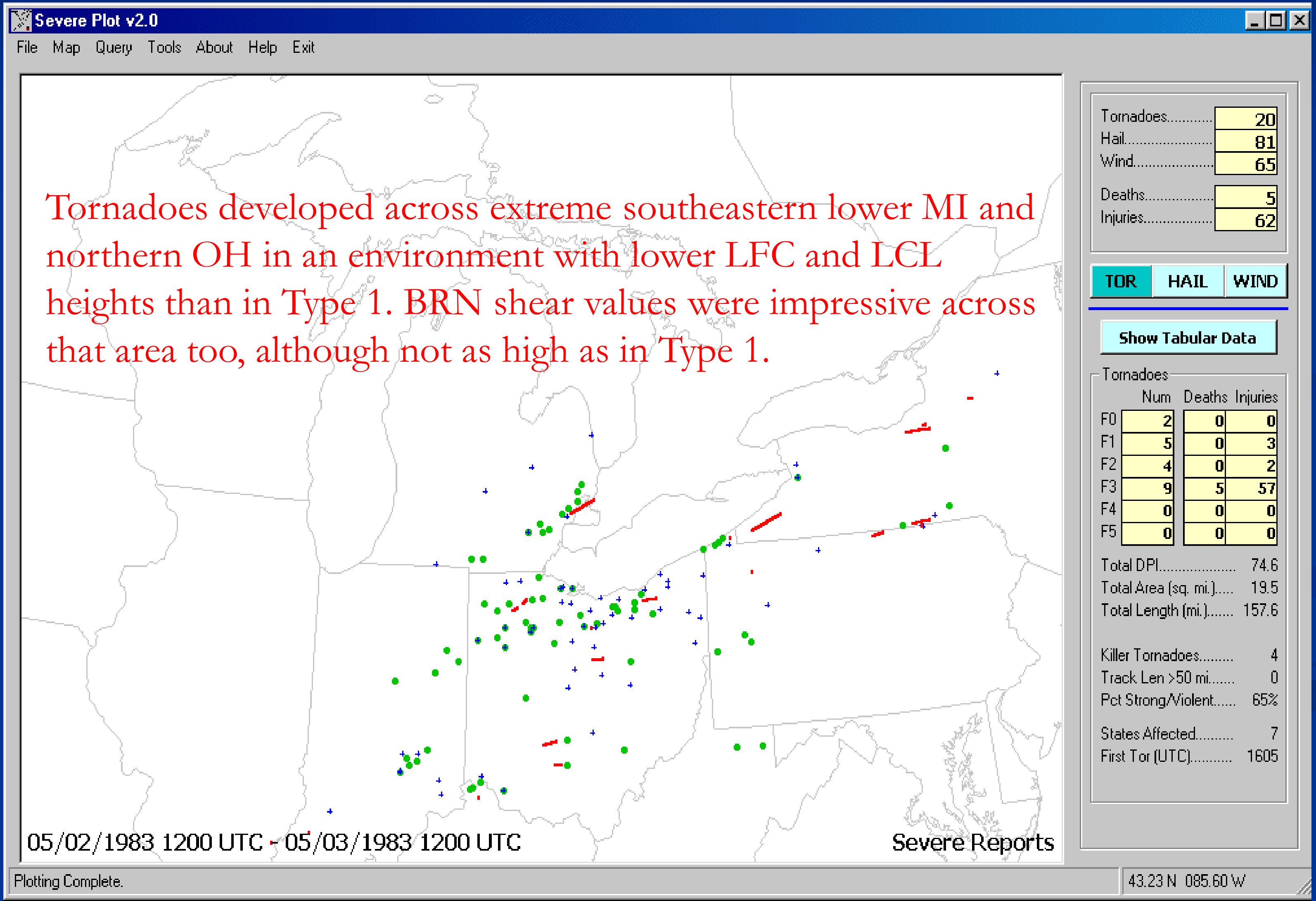
- 00Z sfc chart and sounding indicates cold front going through FNT. Note that speed shear is decent but not nearly as strong as in Type 1; also, obviously the wind fields are more unidirectional w/height well south of the warm front.

5/3/83 @ 00Z - FNT



- 00Z hodograph from FNT indicates decent shear, though not as strong as in the Type 1 case.

Type 2: 5/2/83 Severe Wx Reports



Summary Type 2 Parameters

- Significant BRN Shear values across the Great Lakes. Like Type 1 cases, these are high shear, low CAPE cases. Generally a little less shear, but a little more CAPE than the Type 1 cases.

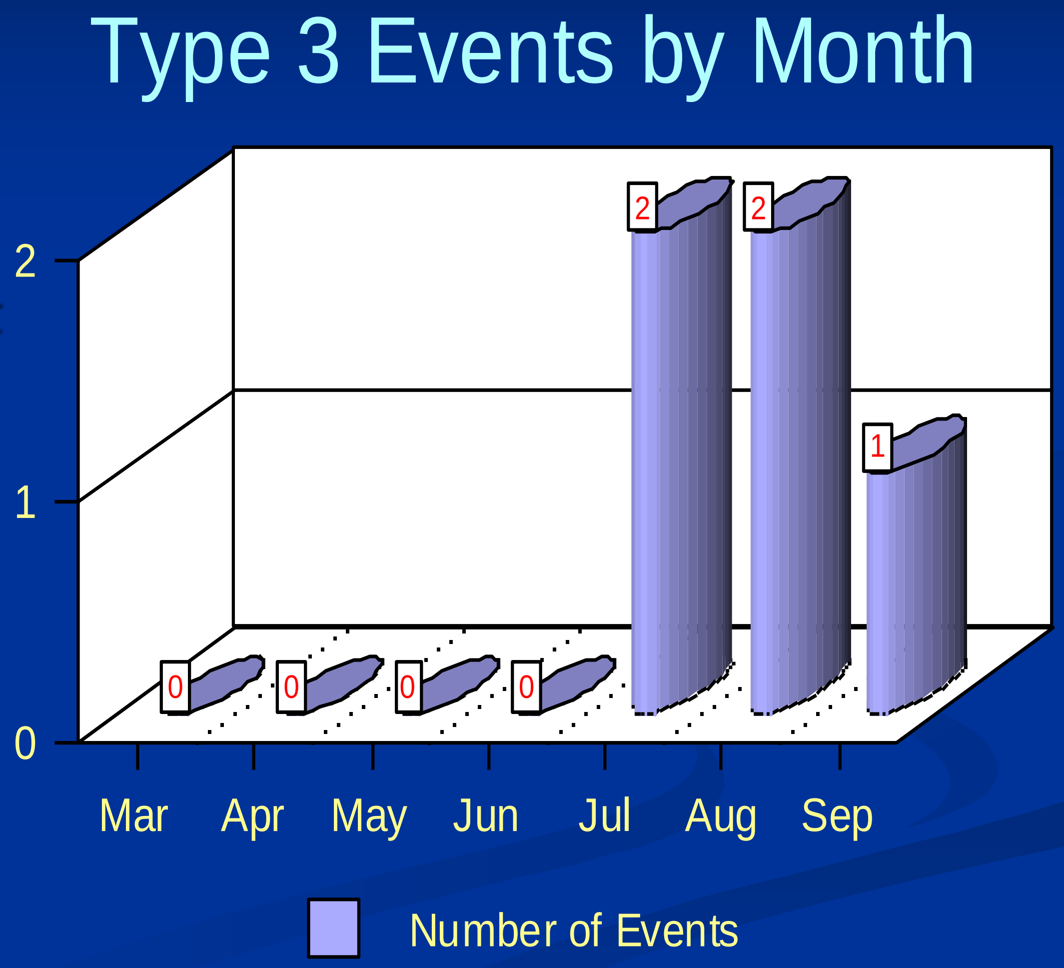
- CAPEs are again unimpressive. CIN values are very favorable (low).

- These environments exhibit very low LFC and LCL heights conducive to the entrainment of low level vorticity. LFC and LCL heights are considerably lower than the Type 1 cases.

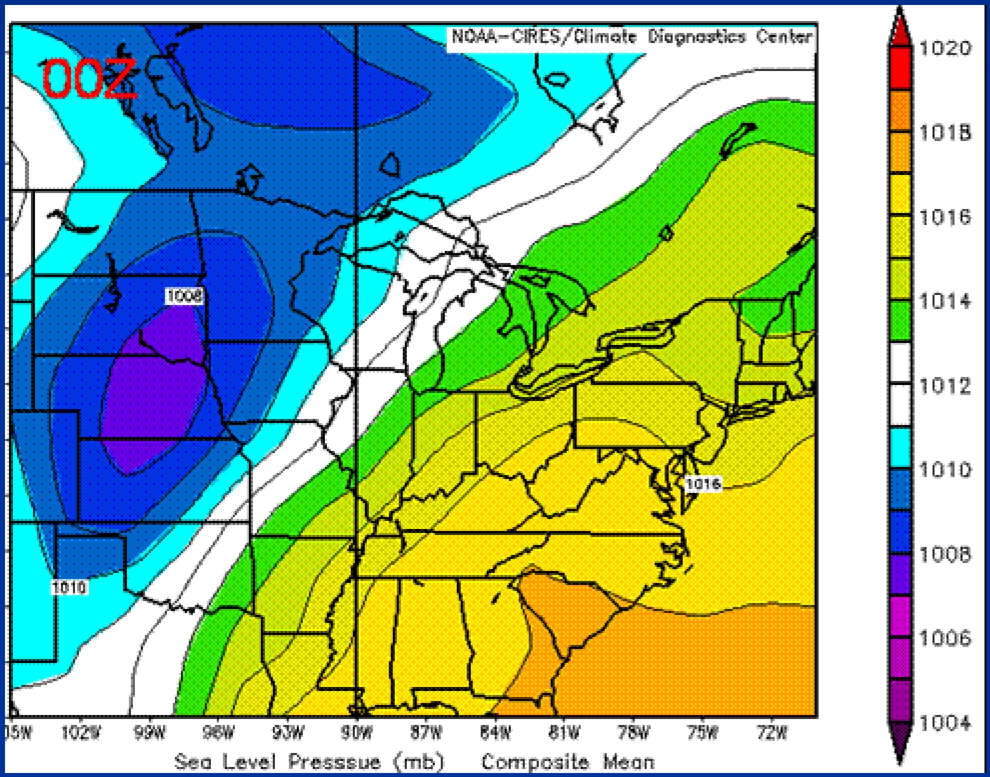
- Modified soundings show significant 0-1 km SRH available in the storm environment. Values are well over 100 m^2/s^2 and over half of the 0-3 km SRH value.

Type 3 Events

- 5 events
- Occurred in July, August or September



MSLP Loop – Type 3



- Stark contrast to Types 1 and 2. These are "late" season (July-Sep) events.
- A much weaker surface low typically develops over the northern Rockies and northern Plains states and tracks west to east without ever really intensifying.

Surface Fields – Type 3

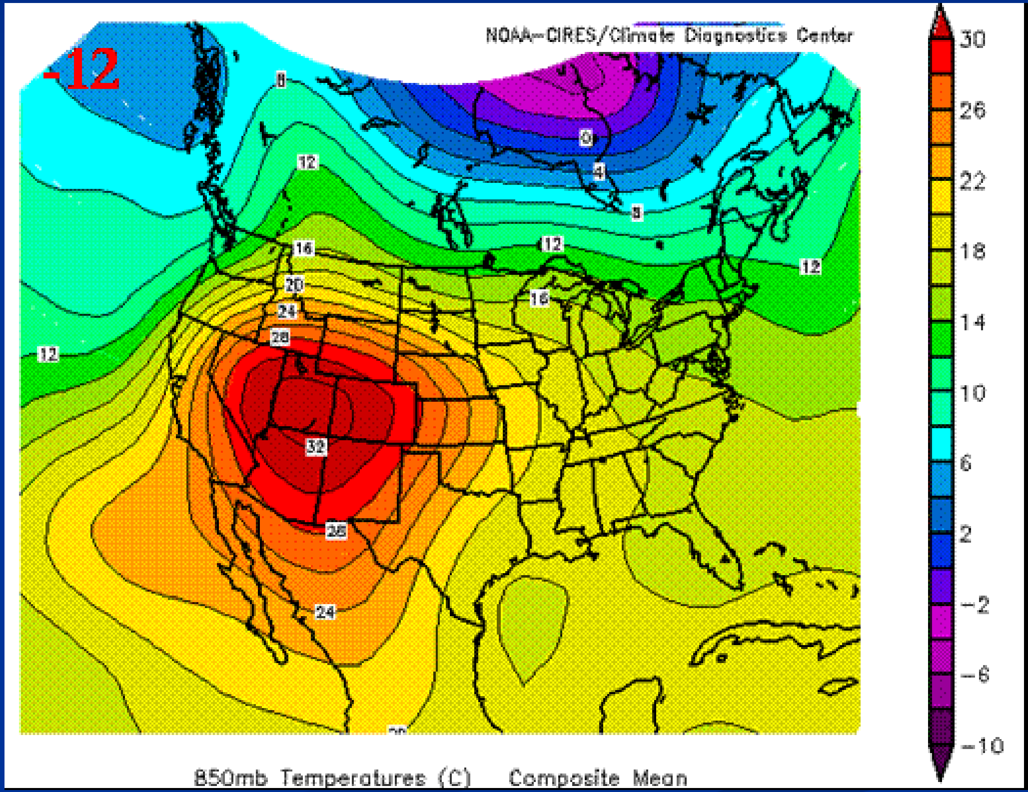
- At 1800 UTC surface temperatures across southern lower Michigan were generally in the 70s and 80s. They ranged from the lower 60s to the mid 90s.

- Surface dewpoints were typically in the mid 60s to lower 70s. They ranged from the upper 50s to the mid 70s.

- Dewpoint depressions typically ranged from 5 to 8 F.

850 MB T Loop – Type 3

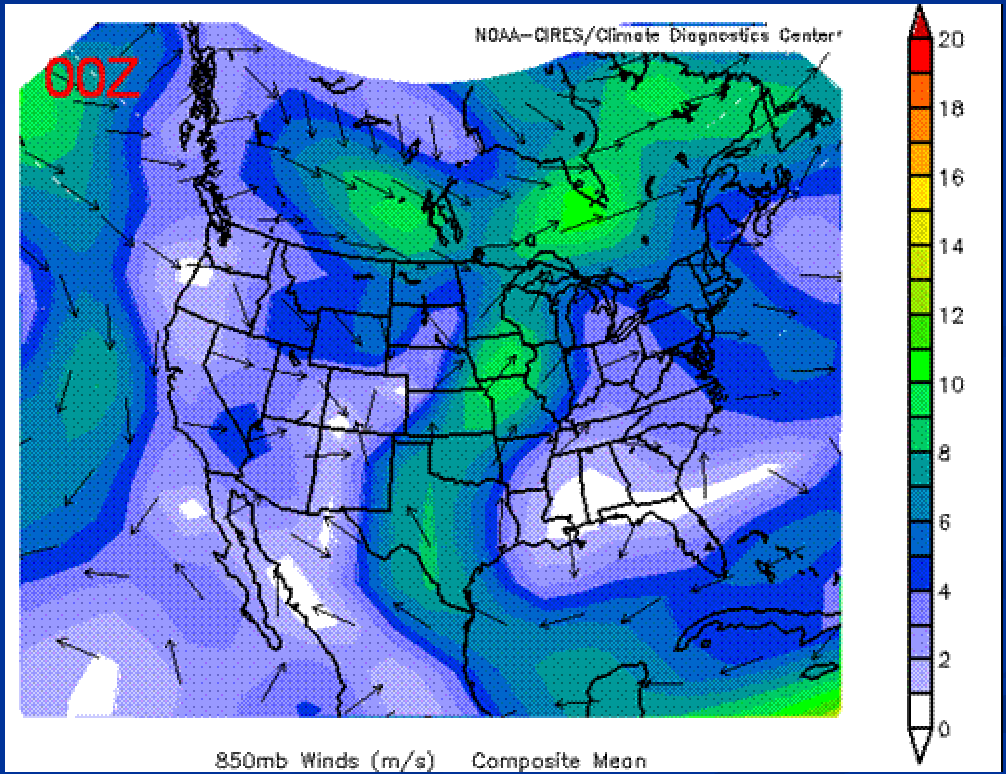
- A weak thermal trough drops into the Great Lakes region. However, 850 mb temps are obviously much warmer this late in the season.



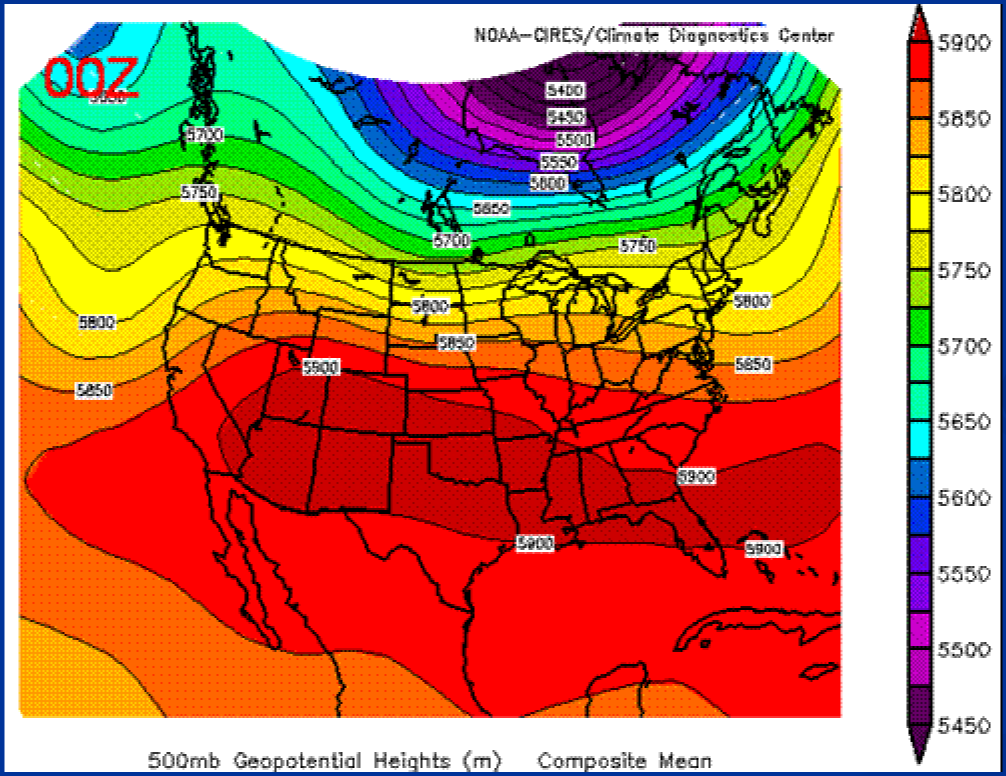
850 MB Winds

A weak 850 mb speed max of around 30 knots passes through IN and OH while 850 wind direction is already veering to the W to WNW.

Both the speed and evolution of the 850 mb wind pattern is markedly different than what we saw for types 1 and 2.

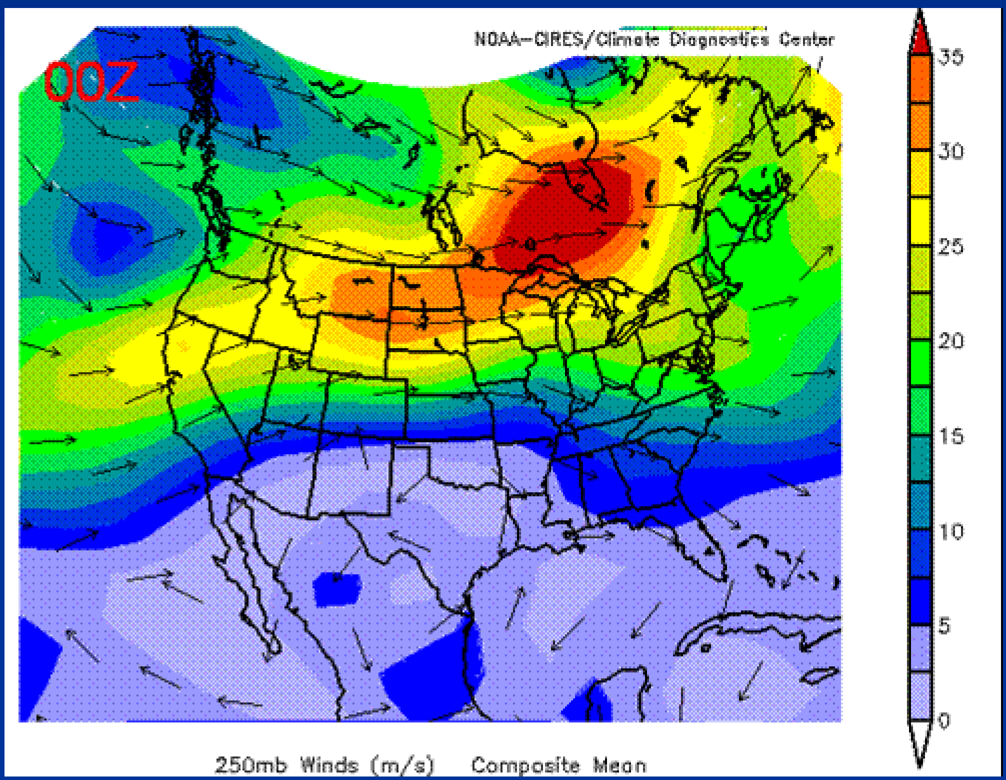


500 MB Heights



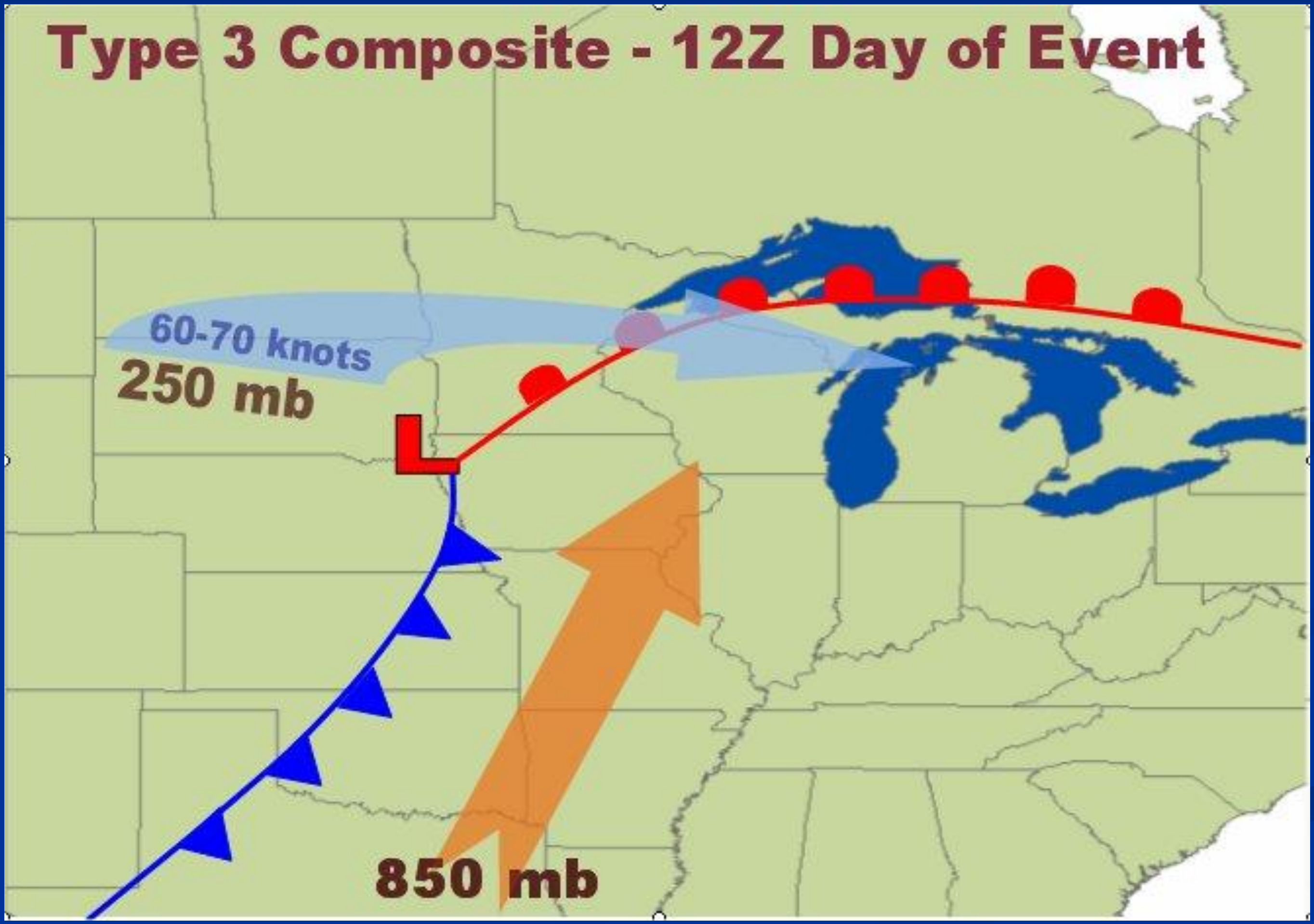
As we would expect, the 500 mb is also much different this late in the season. This composite indicates fairly zonal flow across most of the CONUS. However, a couple of fast moving shortwaves are noted and embedded in the fast zonal flow, moving east from the Northern Plains States

250 MB Winds – Type 3

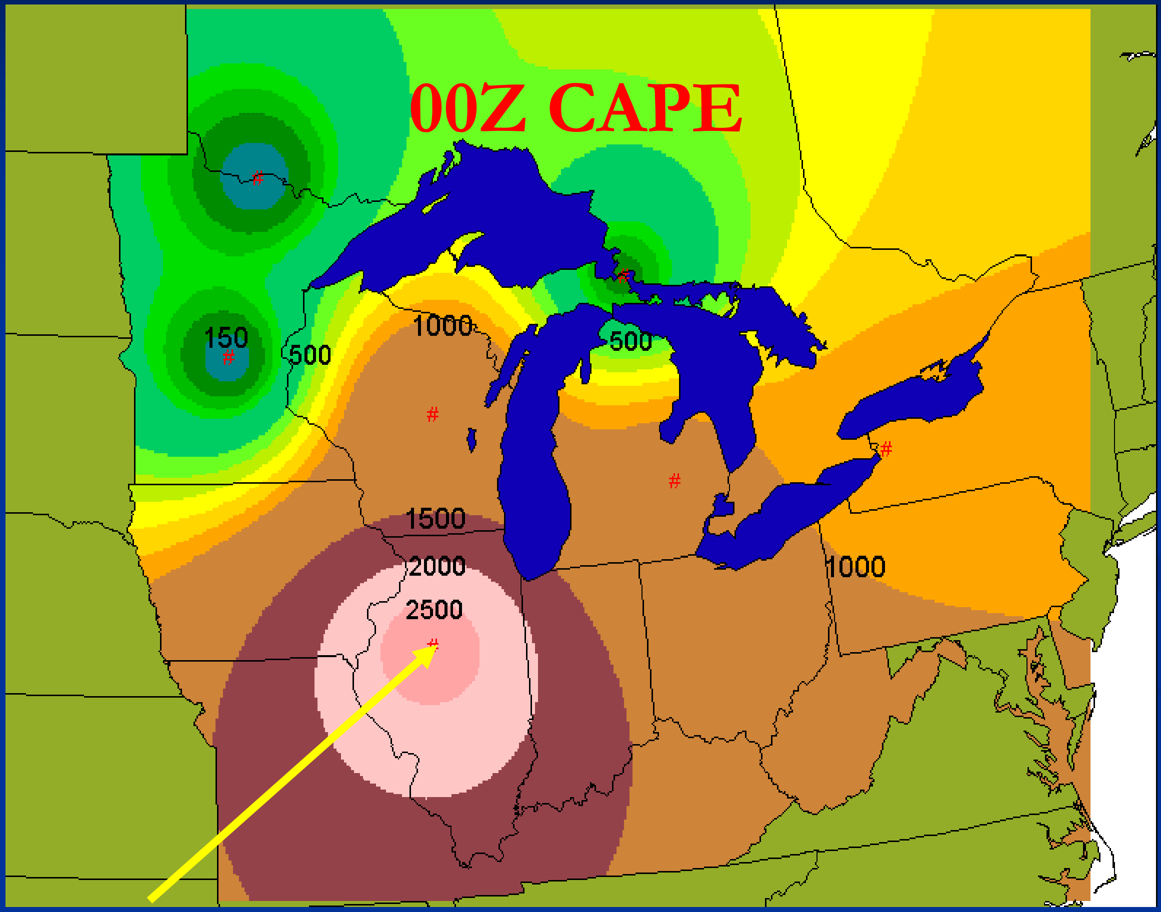


- Much weaker wind fields. A 60-80 kt jet core moves into the northern great lakes region. These are W to NW flow events.

Type 3 - Surface and Upper Air Composite



Type 3 – CAPE (Pmax)

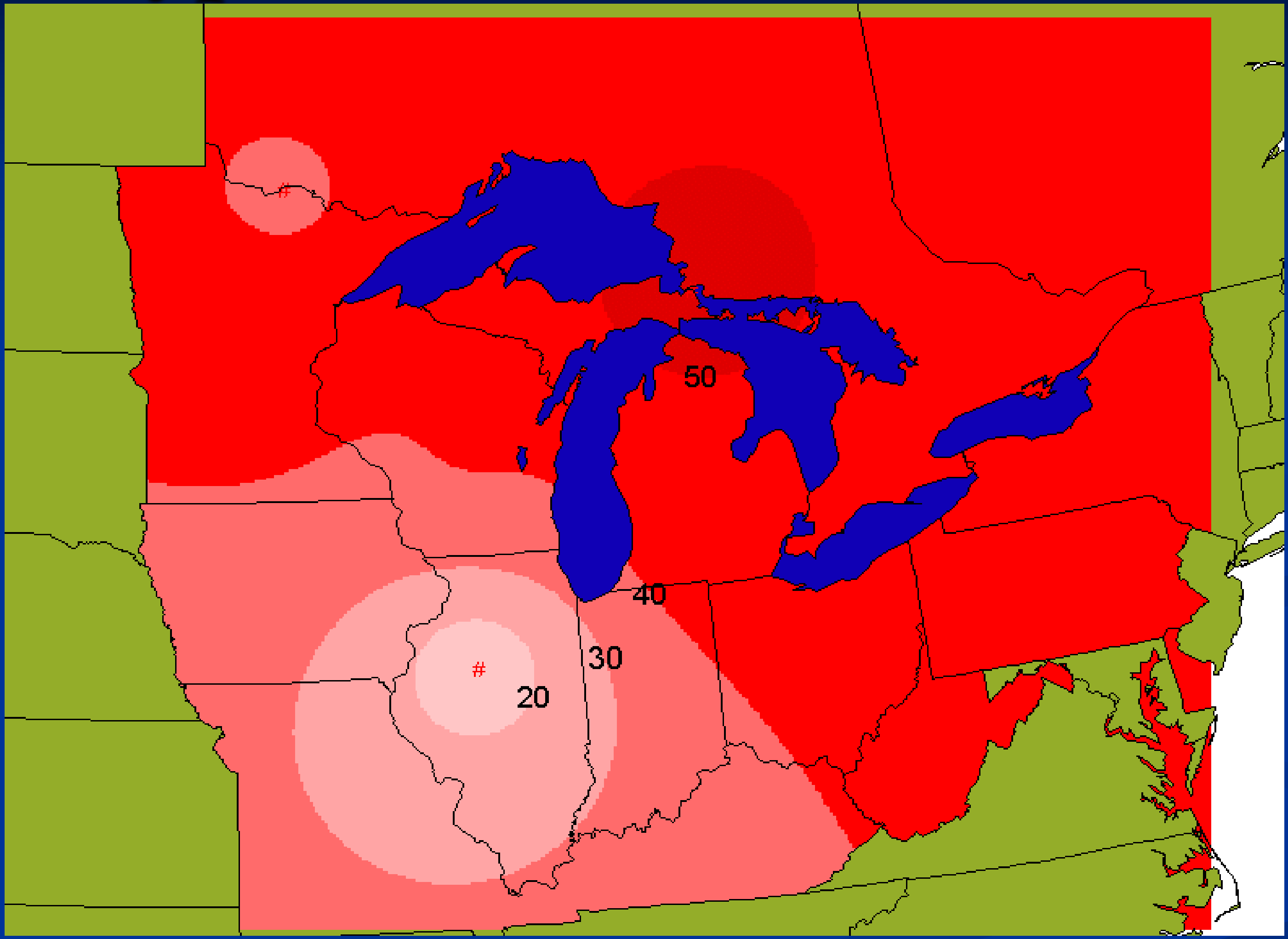


Type 3 cases exhibit the most impressive large scale CAPEs. This is no surprise as these are classic warm sector events.

On average CAPE values were in the 1000-1500 J/kg range at 00Z across lower MI.

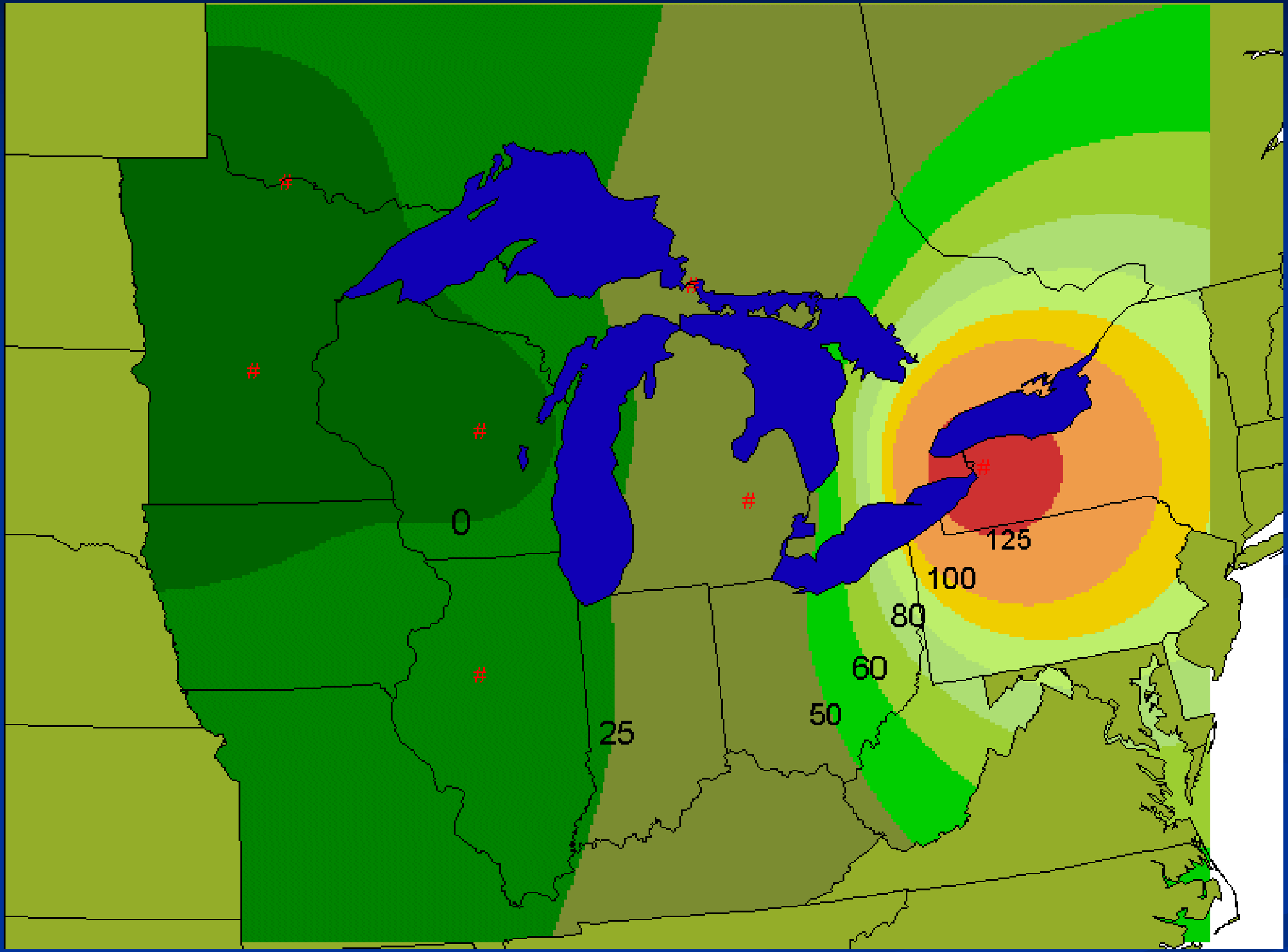
However, soundings modified using representative surface data from around the time of the tornado events yielded CAPE (Pmax) values around **2300 J/kg**.

Type 3 – 00Z BRN Shear



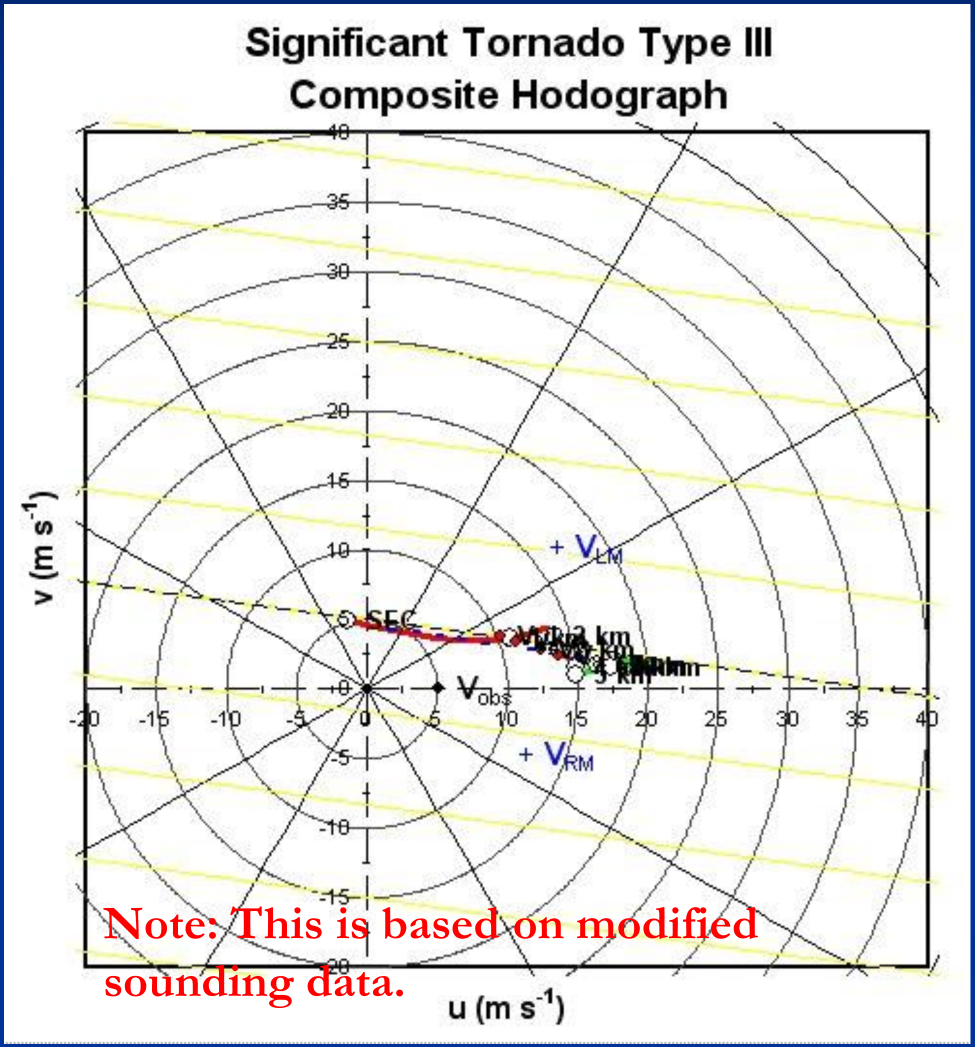
BRN Shear values are by far the lowest for the Type 3 cases. This is indicative of the high CAPE medium shear environment in which they occur. Still BRN Shear values are supportive of supercells.

Type 3 – 00Z 0-3 km SRH



0-3 km SRH values are on the decrease by 00Z across lower Michigan in these cases, as the core of the best low level shear shifts east.

Type 3 – Composite Hodograph



Note: This is based on modified sounding data.

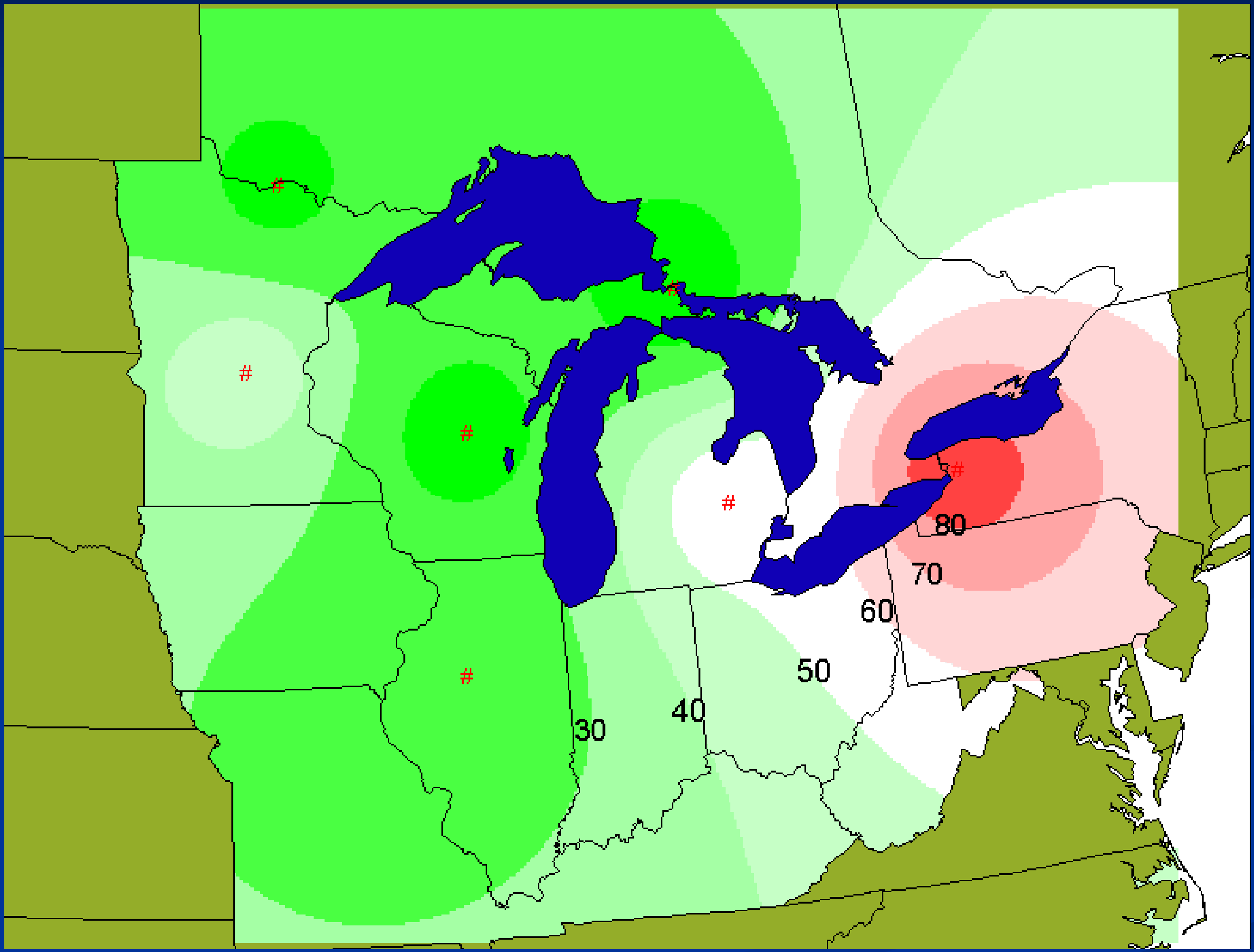
0-1 km SRH 100 m^2/s^2

0-3 km SRH 138 m^2/s^2

0-6 km Shear 17 m/s

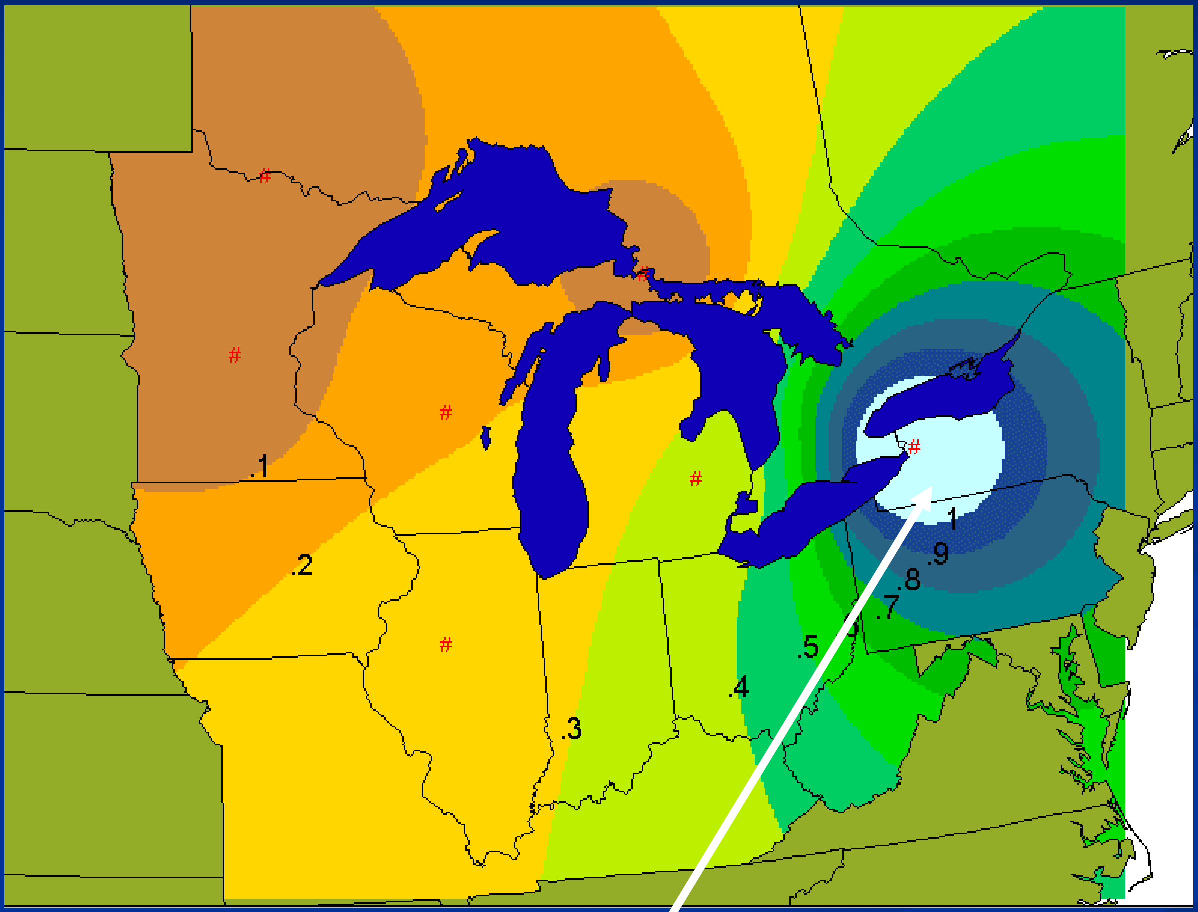
The most important thing to note here is that the 0-1 km SRH value of 100 is about 75% of the 0-3 km SRH.

Type 3 – 00Z CIN



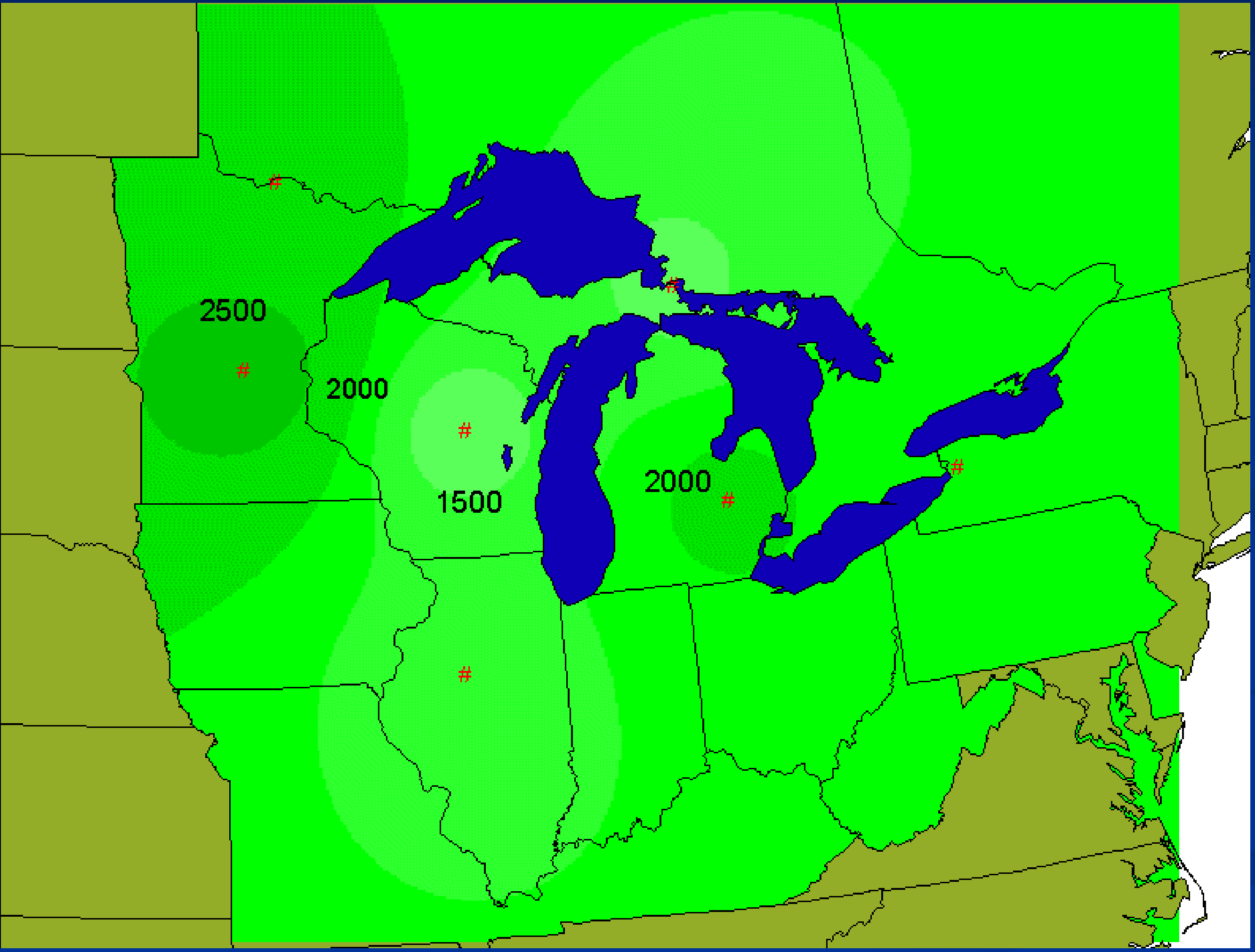
Lower Michigan is in the CIN gradient in Type 3 cases. CIN values are relatively low across lower Michigan, although not ideal.

Type 3 – 00Z EHI



These cases have the best core of EHI values, but it is shifted to the east of Michigan by 00Z.

Type 3 – LFC Heights (m)

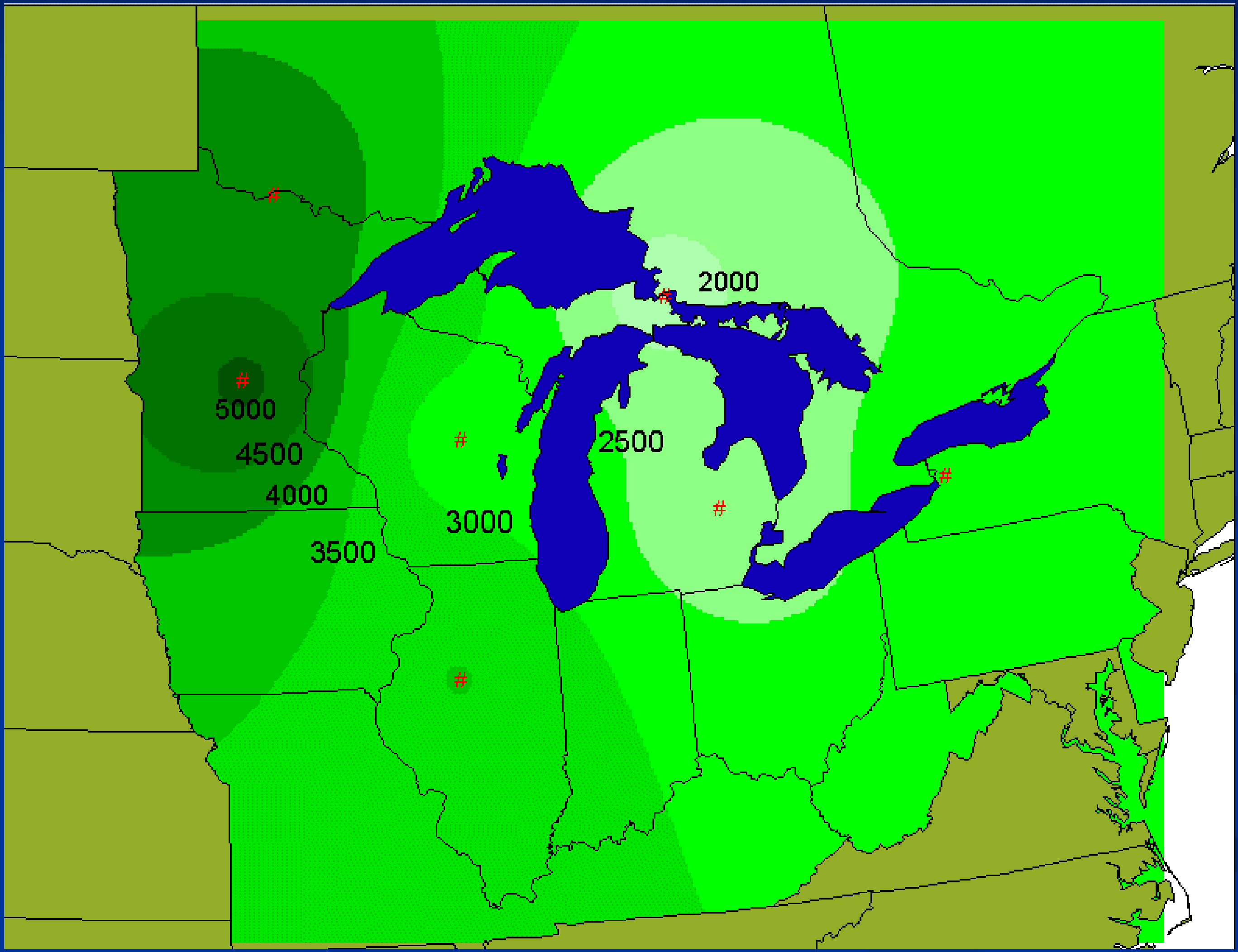


On average 00Z LFC values were 1500-2000 m across lower Michigan.

Soundings modified using representative surface data from around the time of the tornado events yielded LFC heights around **1400 m**

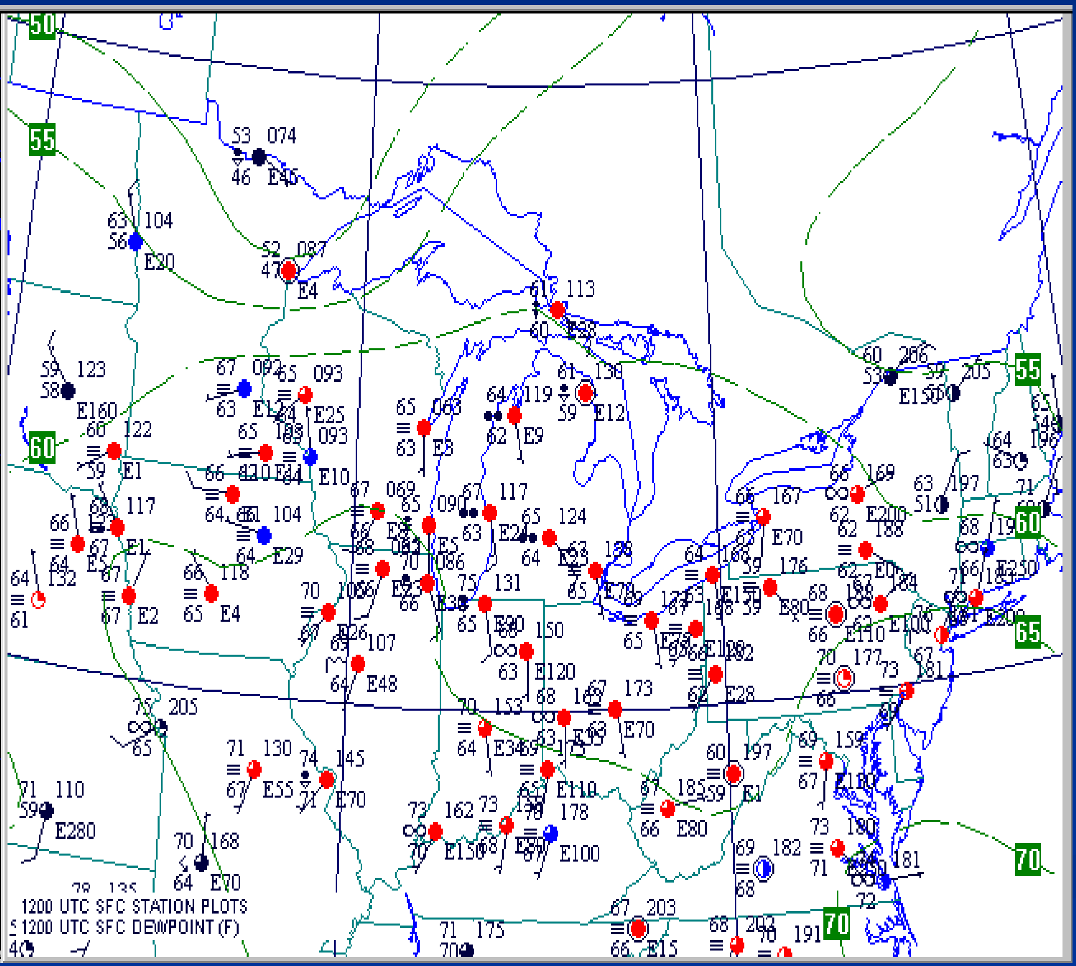
LFC heights are pretty favorable in the Type 3 events, but higher than the Type 2 events.

Type 3 – 00Z LCL (ft)



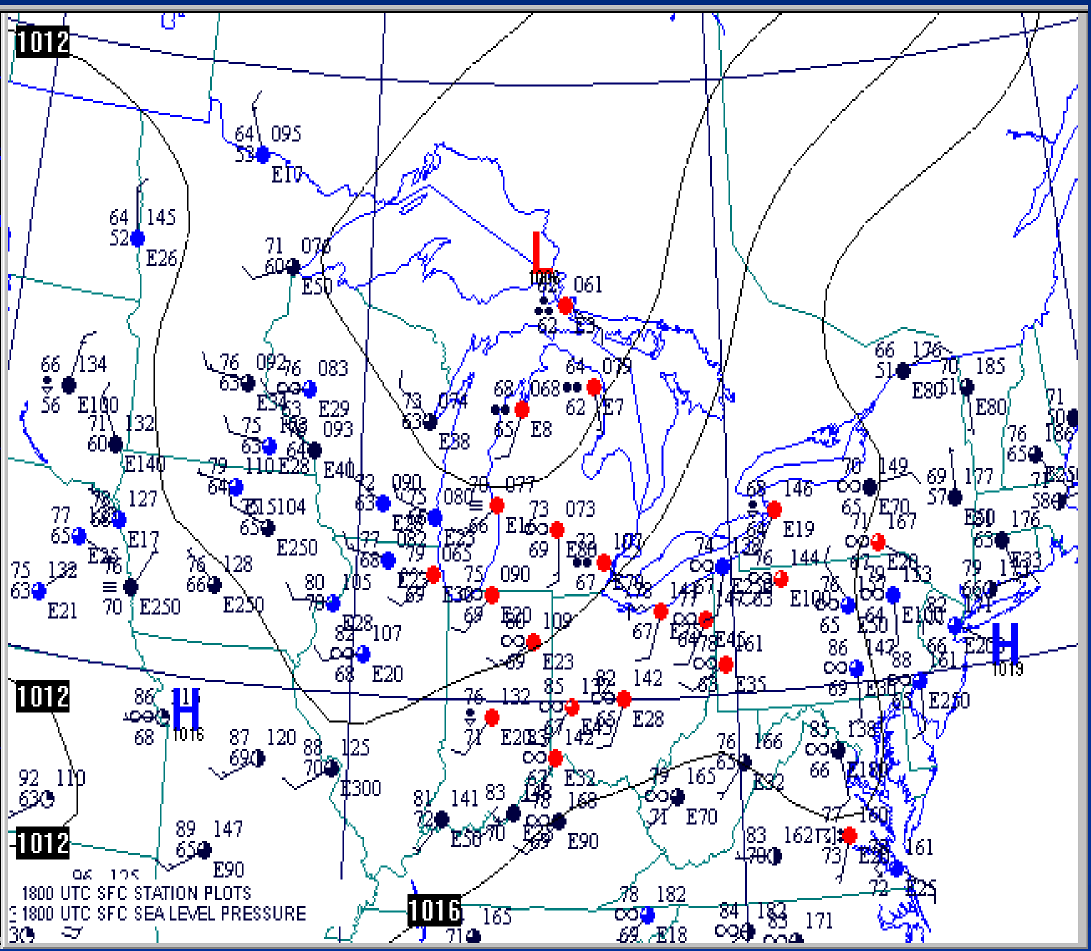
LCL Heights are relatively low and favorable for significant tornadoes.

"Classic" Type 3 Event: 8/2/72 @ 12Z



- Weak low pressure located over northeast MN with cold front moving into western WI and eastern IA
- Dew points across most of lower MI are in the 60s out ahead of it.

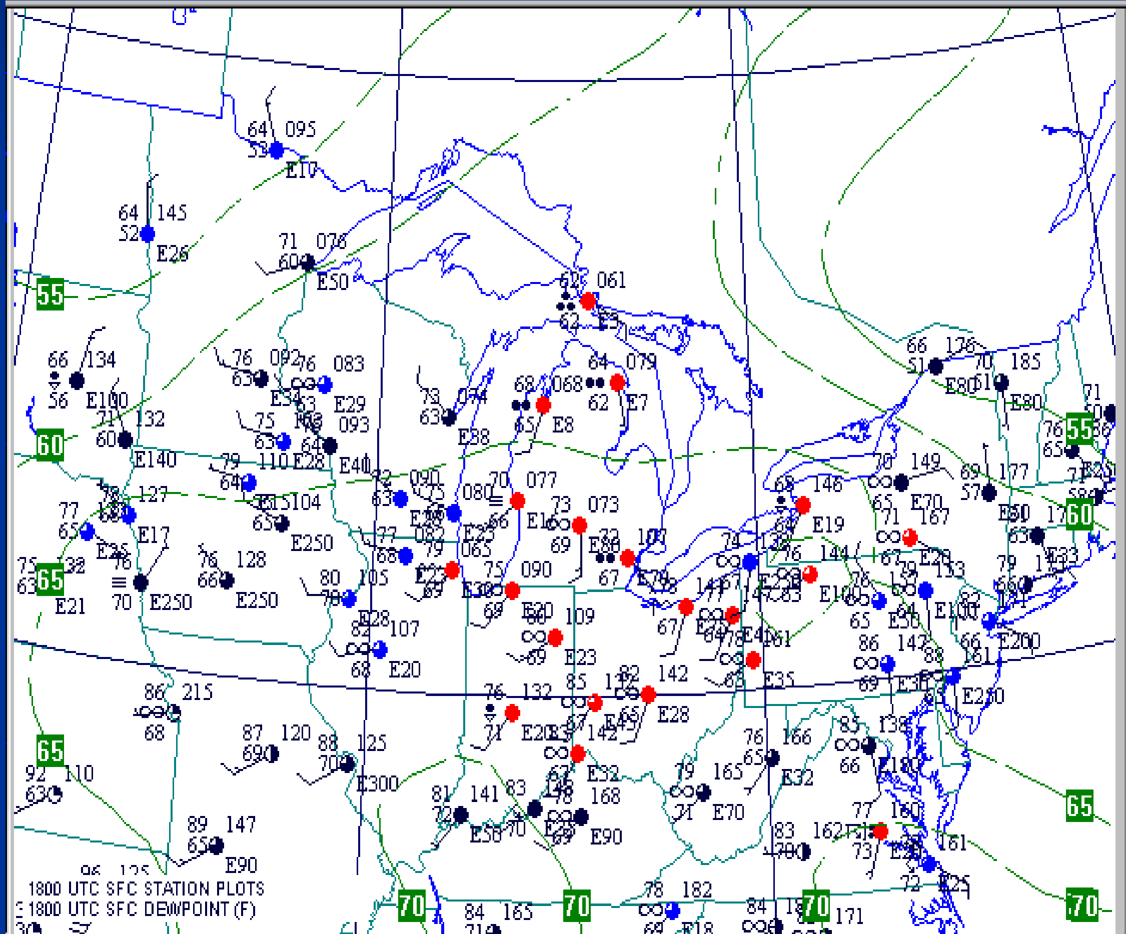
Type 3 Event: 8/2/72 @ 18Z



- Weak sfc low has tracked east to near SSM with cold front moving across Lake MI.

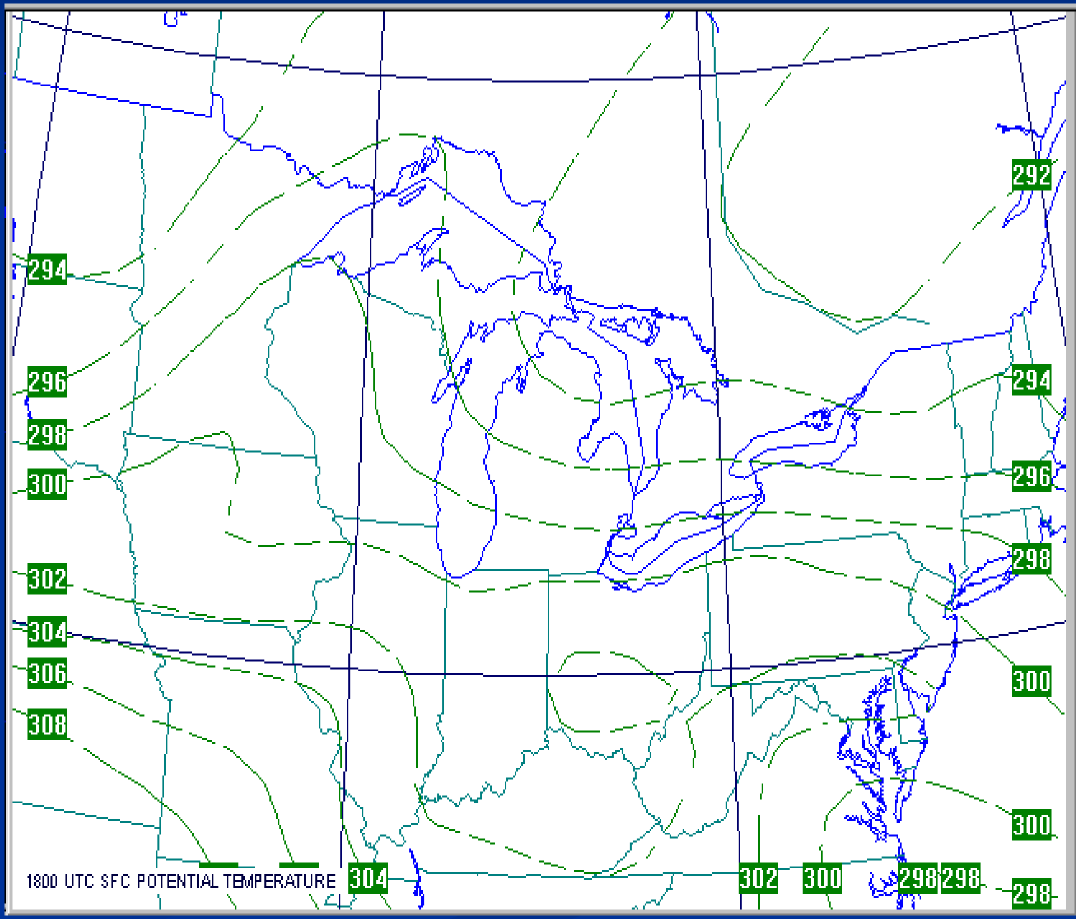
Type 3 Event: 8/2/72 @ 18Z

- Dew points have climbed into the lower to middle 60s across northern lower MI and into the upper 60s across southern MI

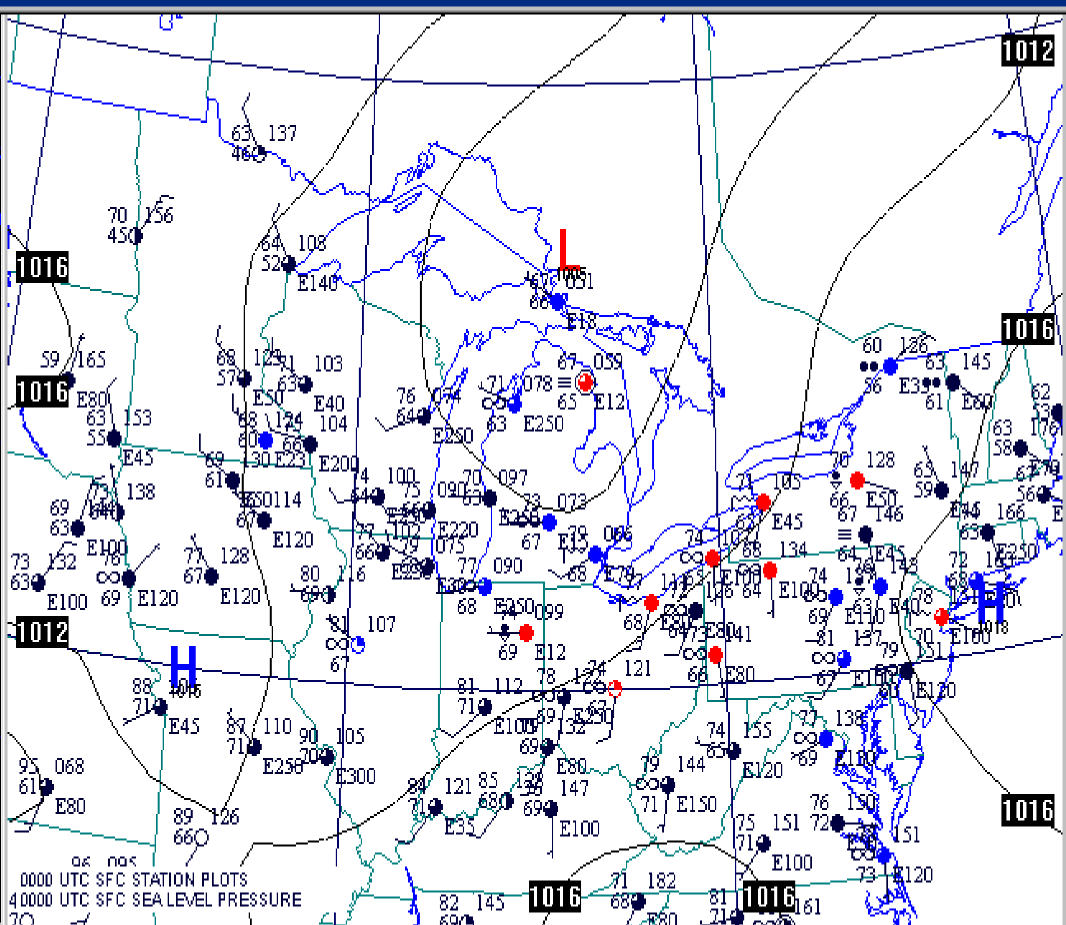


Type 3 Event: 8/2/72 @ 18Z

- Theta e analysis also indicates considerable moisture, particularly across southern lower MI

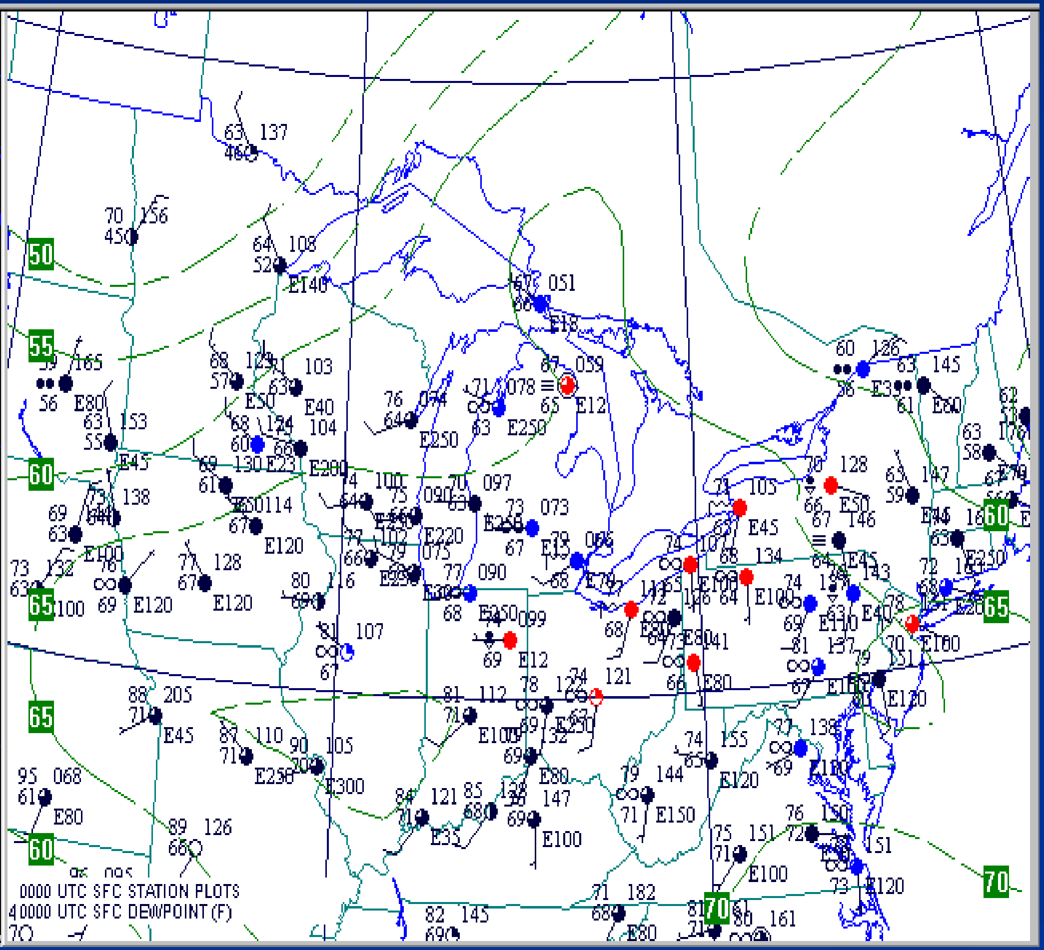


Type 3 Event: 8/3/72 @ 00Z



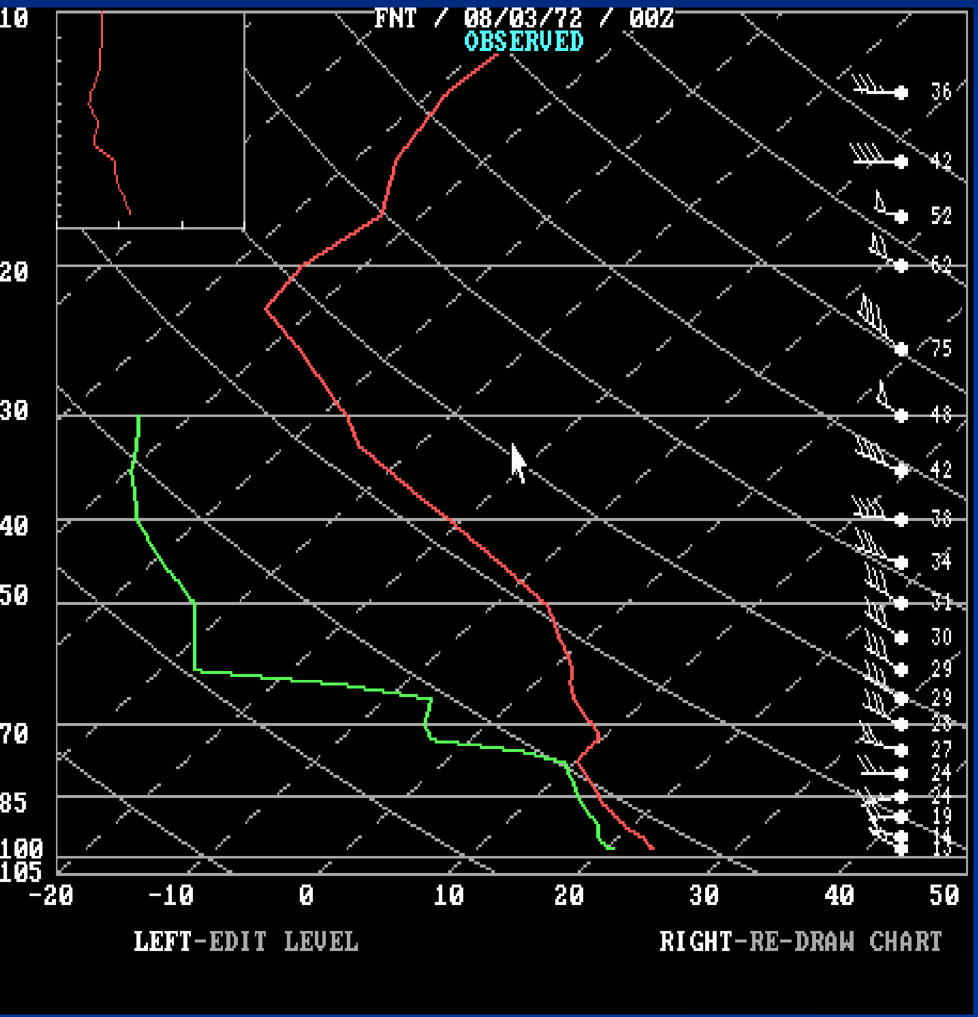
- Weak low pressure near SSM with cold front moving through central lower Michigan.

Type 3 Event: 8/3/72 @ 00Z



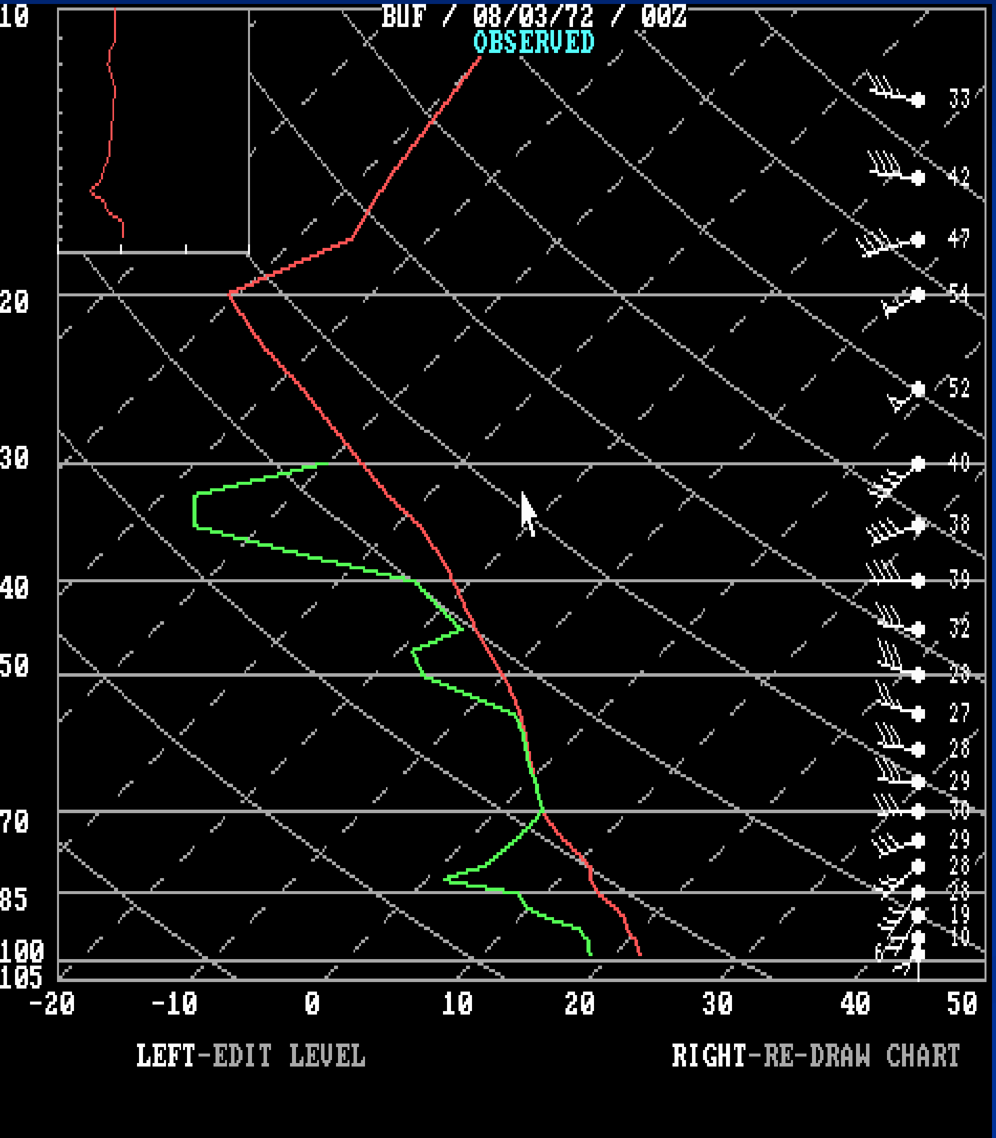
- Dew points still in the 60s across lower MI.

8/3/72 @ 00Z - FNT



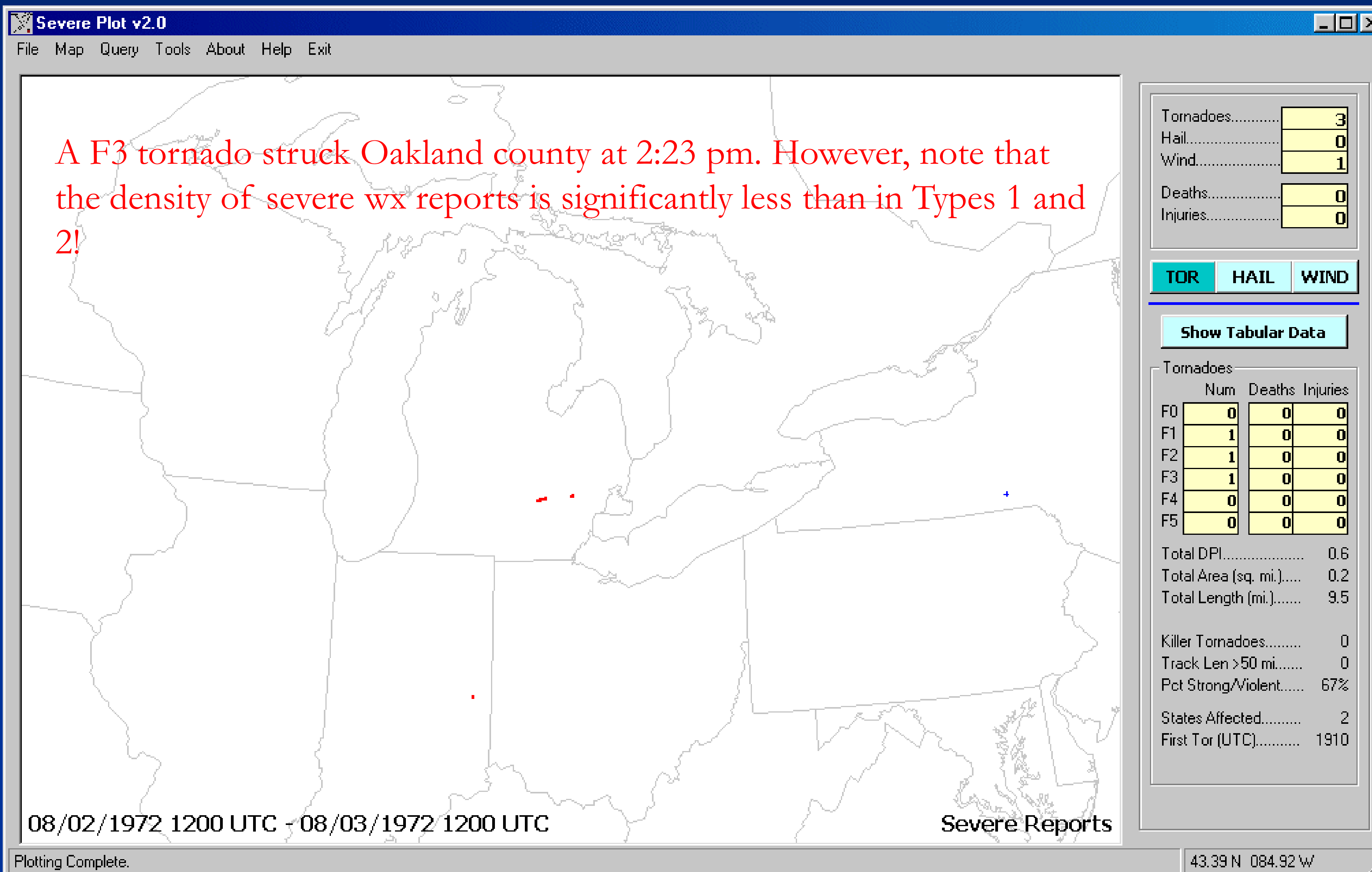
- Cold front just moving through FNT. Fairly unidirectional WNW wind profile with height. Note abundant moisture from around 800 mb down to the surface with much drier air at the mid and upper levels. All the moisture in the lower levels contributes to lower LCL heights conducive to tornadoes. Also can envision a scenario just a few hours earlier than this where low level wind fields would have been more from the S to SW ahead of the cold front. Since we're in the warm sector these are high CAPE events too… CAPE was likely impressive several hours before this sounding was obtained.

8/3/72 @ 00Z - BUF



- Note that BUF's sounding indicates better directional shear; This was also confirmed earlier by high 0-3 km SRH values graphic.

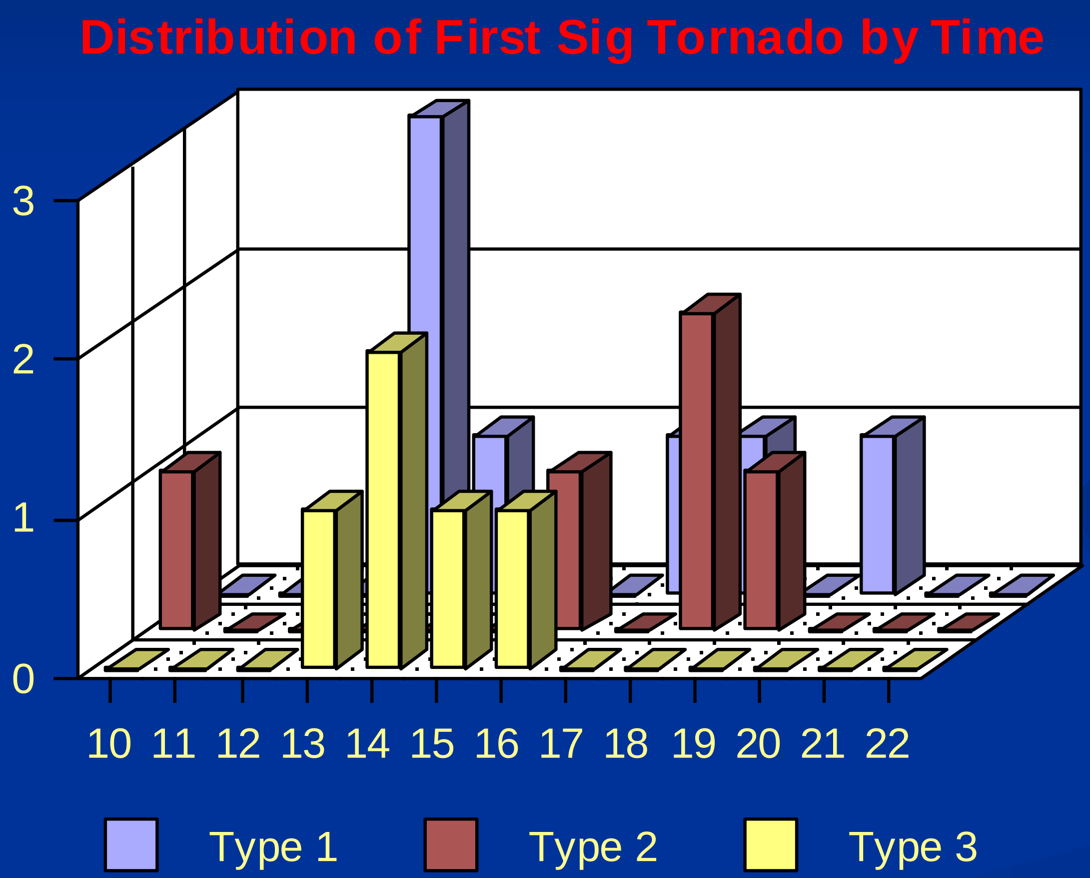
Type 3: 8/2/72 Severe Wx Reports



Summary Type 3 Parameters

- Type 3 cases exhibit more of a high CAPE marginal shear environment. BRN Shear values are supportive of supercells, but on the low end of the scale.
- Despite lower deep layer shear values, modified soundings show significant 0-1 km SRH available in the storm environment. 0-1 SRH values averaged around 100 m^2/s^2 which was nearly 75% of the 0-3 km SRH values.
- LFC and LCL heights are reasonably low.

Distribution of Tornado Events for Each Type by Time of Day



- Type 1 and 2 events typically begin anywhere from early afternoon well into the evening.
- On the other hand Type 3 tornadoes events tend to be confined from early to mid afternoon.

Note that time is based on a 24 hour clock such that 13 equals 100 PM.

Conclusions

Comparing & Contrasting Types 1-3

TYPE ONE
- Very strong sfc low
- 130 knot plus 250 mb jet
- Very high BRN shear values
- Fairly strong 0-3 km SRH
- Warm front usually across or just south of our CWA at 12Z and meandering across it or lifting slowly north
- Very high shear environment which produces the largest, deadliest tornado outbreaks from March through May.

TYPE TWO
- Warm front already across northern lower MI at 12Z
- Lower LFC/LCL values than in Type 1 (more low level moisture is a contributing factor since we're south of the warm front at 12Z already)
- Low CIN
- High BRN shear (though typically not as high as in Type 1).
- March through May

TYPE THREE
- Radically different than types 1 and 2
- July through September
- Very weak sfc low develops over northern Rockies or Plains states and tracks east; low never really intensifies
- BRN shear values are (by far) the lowest of the 3 Types. This is indicative of the high CAPE/medium shear warm sector environments in which they develop.

The Future of the Significant Tornado Climatology for Lower MI

- Randy discovered that historical data is available on the Climate Data Center web site, going back to 1948. To this point we were limited by data availability on the NMC historical data cd-roms.

- This data will allow us to expand the Sig Tor Climo from 1951 to 2000, a comprehensive 50 year tornado climatology for lower Michigan. This is significant because obviously, a more complete data set allows for more conclusive research results, and lower MI had several violent tornadoes in the 1950's.

- Then we are going to write a paper on all of this, and try and get published a 50 year Significant Tornado Climatology for Lower Michigan.

May 13, 1980 Kalamazoo Case Study

- We also continue to work on the May 13th 1980 Kalamazoo case (one of the "Type One" events). This is a spinoff of our Sig Tor Climo. It was the last significant tornado to strike the GRR CWA and cause fatalities (5), so we thought it would be a great case to examine in even greater detail.
- We've already generated a 66 page report on it (MS Word document), including a methodology, review of large scale synoptic conditions, hourly surface weather map analysis, observed and modified soundings and data derived from them, observed and modified hodographs and data derived from them, chronology of events occurring across Van Buren and Kalamazoo counties, Kalamazoo storm damage survey findings from Fujita, and testimonials and pictures from Kalamazoo Gazette archives.
- We've also taken some of the very latest tornado research from our Sig Tor Climo, SPC, Rasmussen, Markowski, 2002 Tornado Warning Guidance and applied it directly to the AZO case. This is in an effort to learn more apply our knowledge, rather than just a traditional case study that states what happened.

Null - Events

- Some of you may have wondered why once in a while it appears we have an excellent synoptic scale setup for a major severe weather event, yet nothing materializes.

- *A knowledge of the history of significant MI tornadoes and recognizing which patterns produced them is a vital first step. We think this climatology has come a long way in achieving this goal, but we are still working hard to learn more and add more to the climatology (inclusion of 50's cases, write paper on all of this, etc).*

- *Once pattern recognition is established, whether an event materializes or not lies in all the very fine meso and microscale details that are too extensive to list here (i.e., are we getting any sun and surface based instability, is there a cap, where are the boundaries, is there a dryline or pseudo-dryline, etc). Timing is extremely critical. Obviously, all the ingredients have to come together just right for tornadogenesis to occur.*

References

- Davies, John, 2002: A Primer on Low-level Thermodynamic Parameters When Assessing Supercell Tornado Environments http://members.cox.net/jondavies1/LLbuoyprimer/LLbuoyprimer.htm

- Rasmussen, E. N., and D. O. Blanchard, 1998: A baseline climatology of sounding-derived supercell and tornado forecast parameters. *Wea. Forecasting*, **13**, 1148-1164.

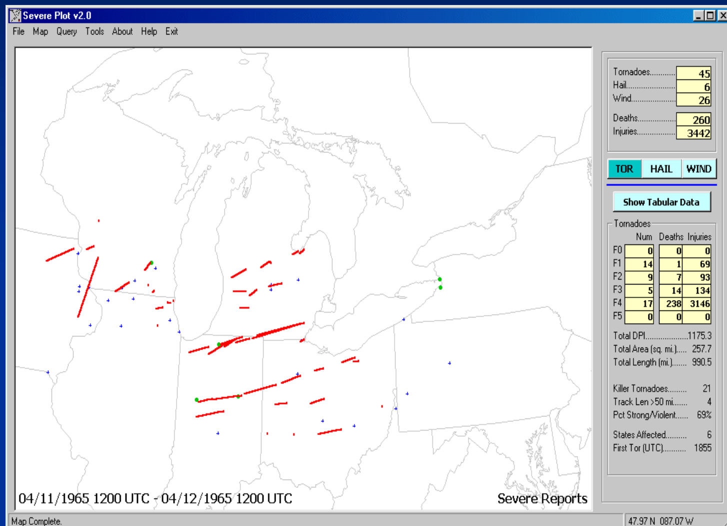
- Markowski, P. M., E. N. Rasmussen, and J. M. Straka, 1998a: The occurrence of tornadoes in supercells interacting with boundaries during VORTEX-95. Wea. Forecasting, 13, 852-859.

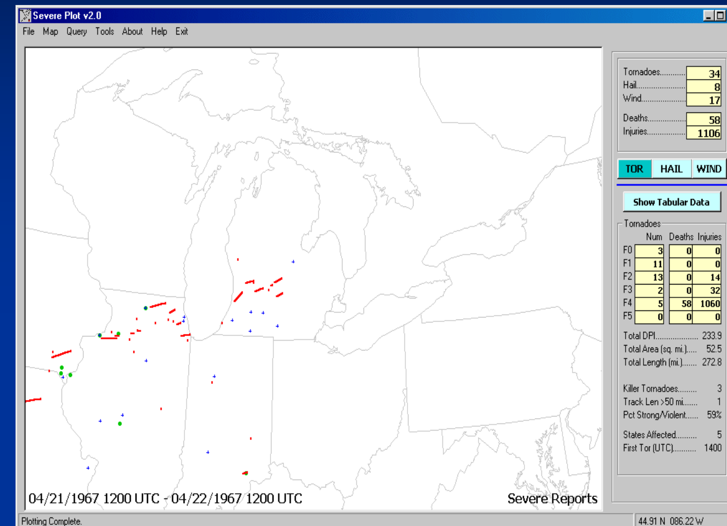
- Markowski, P. M., J. M. Straka, and E. N. Rasmussen, 1998b: A preliminary investigation of the importance of helicity 'location' in the hodograph. Preprints, 19th Conf. on Severe Local Storms, Minneapolis, MN, Amer. Meteor. Soc., 230-233.

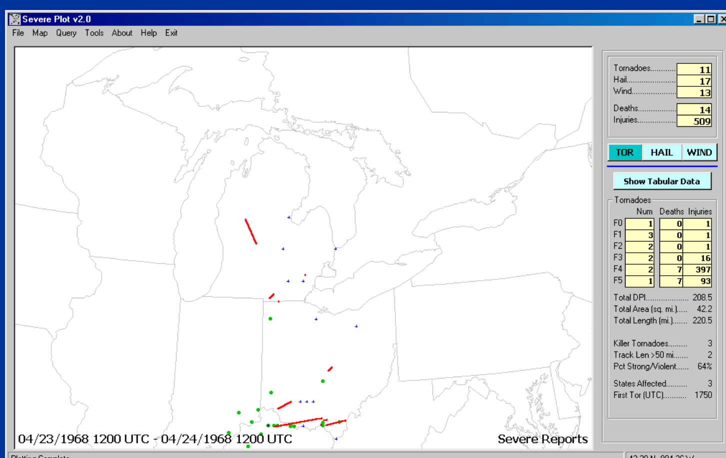
References (cont'd)

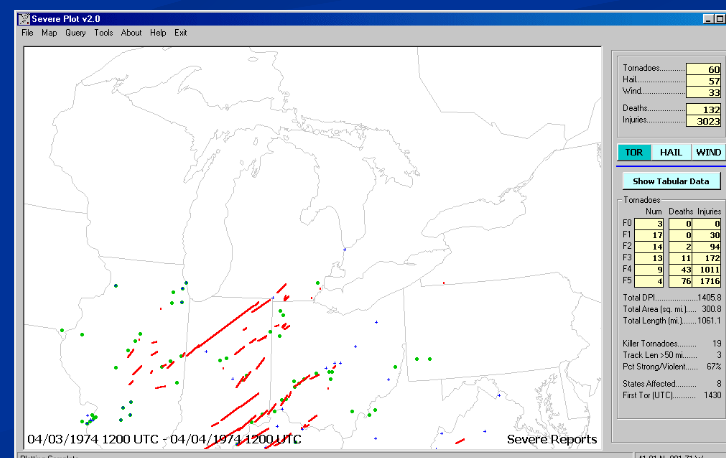
- Grazulis, Thomas P. "Significant Tornadoes 1680 to 1991."
- Fujita, T. Theodore "U.S. Tornadoes, Part 1, 70 year statistics."

Type 1 Storm Reports

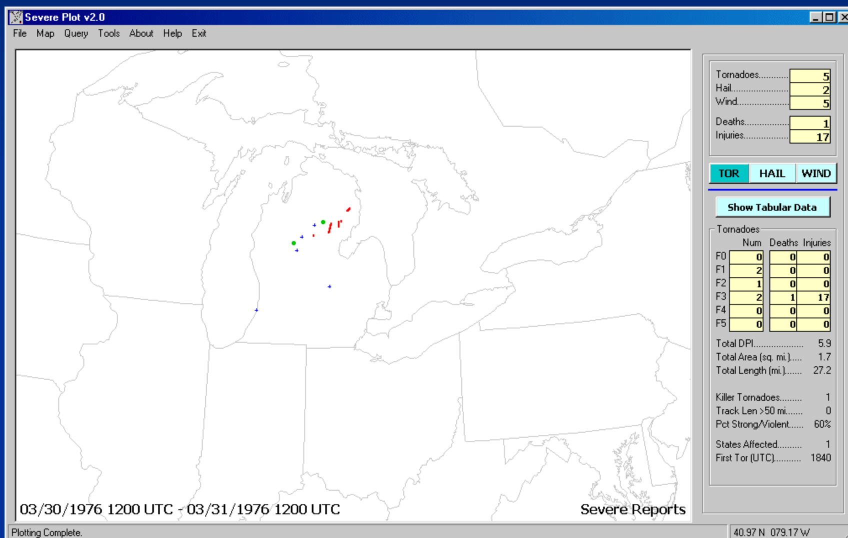


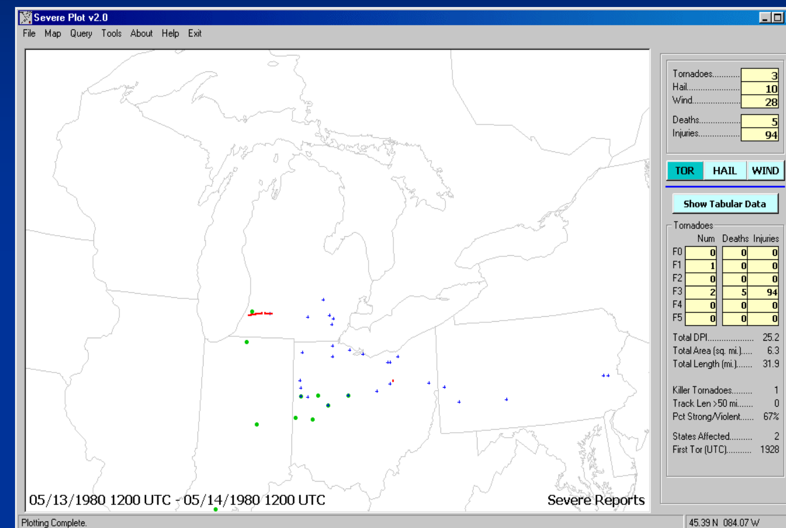


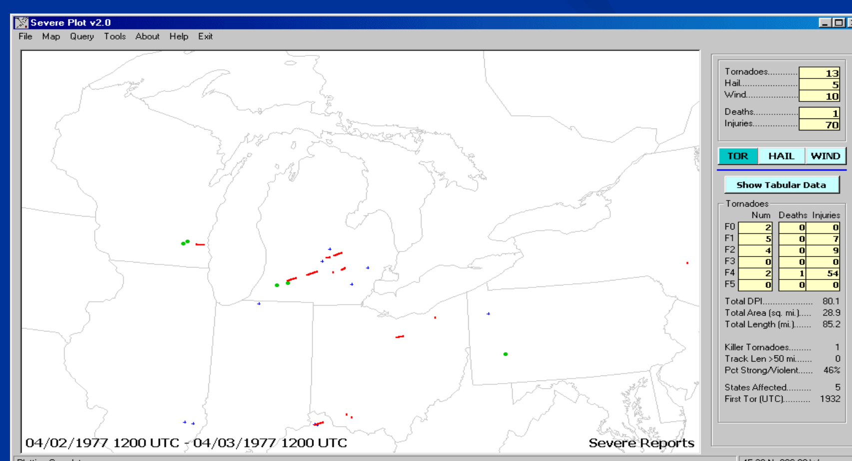




Type 1 Storm Reports (cont'd)





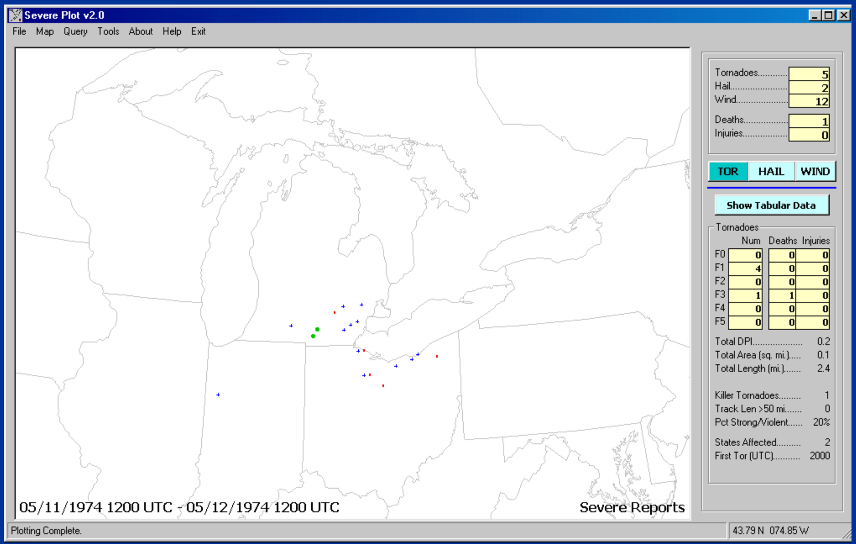


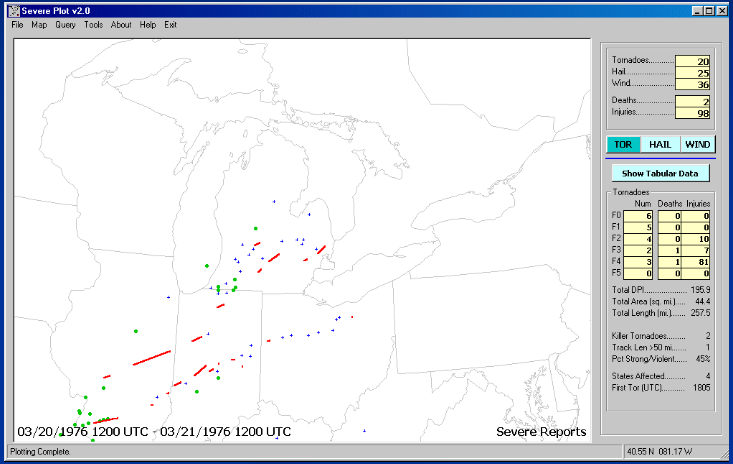
Type 1 Storm Reports

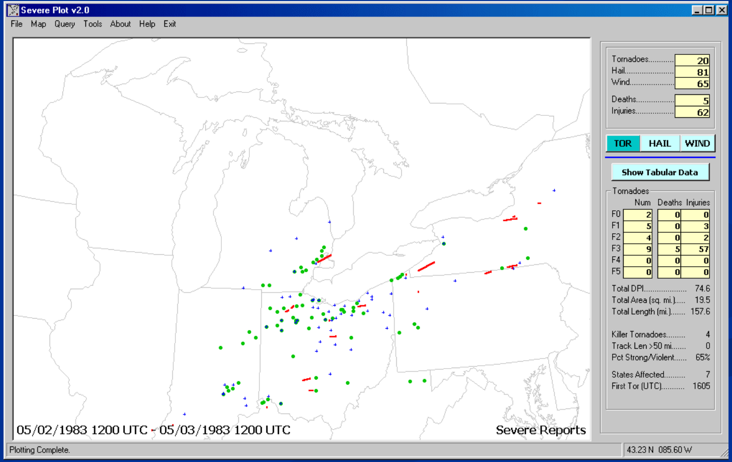
- Very significant, large family tornado outbreaks in Type 1. Although these are possible in Type 2, generally in Type 2 outbreaks, the tornado density is not nearly as widespread.

- ***4 of 7 Type 1 Events produced F4 tornadoes. Only 1 Type 2 Event produced an F4, and no Type 3 Events produced F4's.***

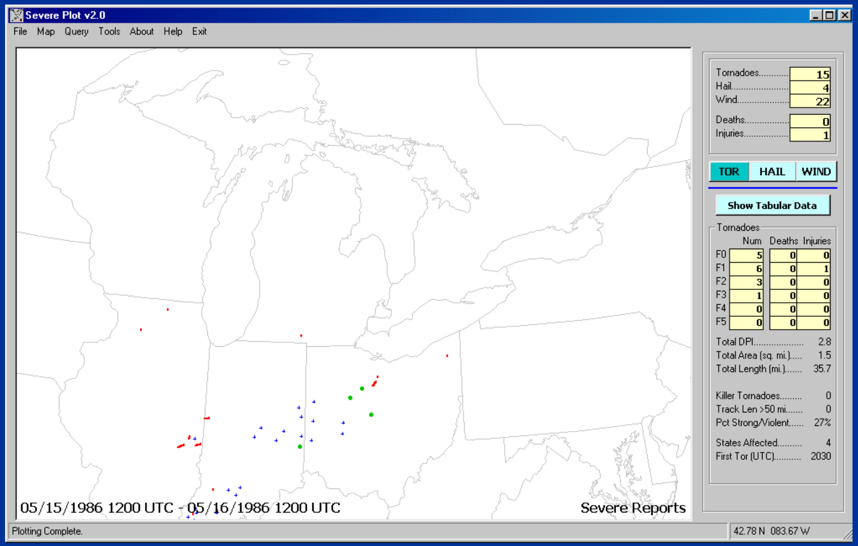
Type 2 Storm Reports

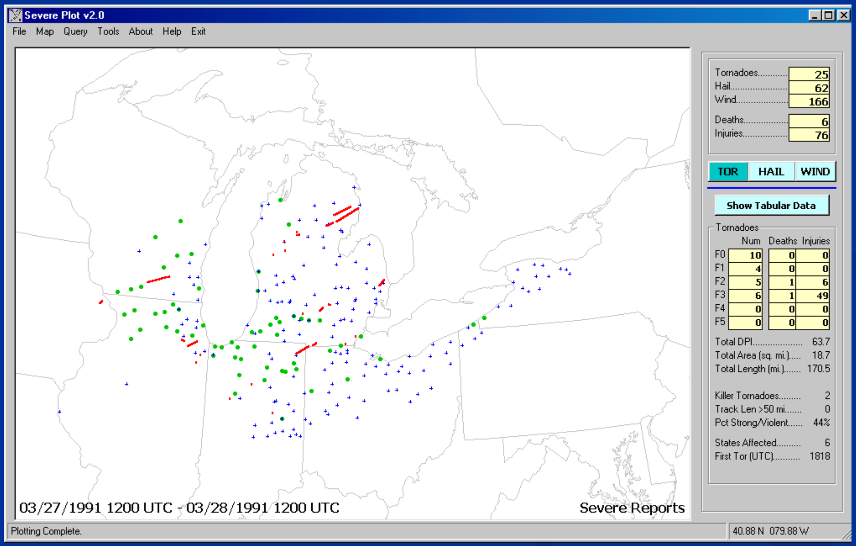






Type 2 Storm Reports

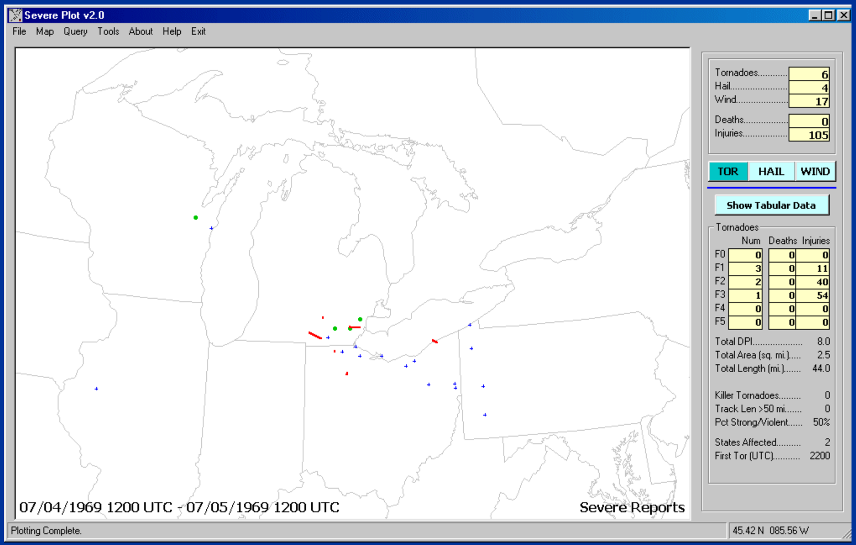


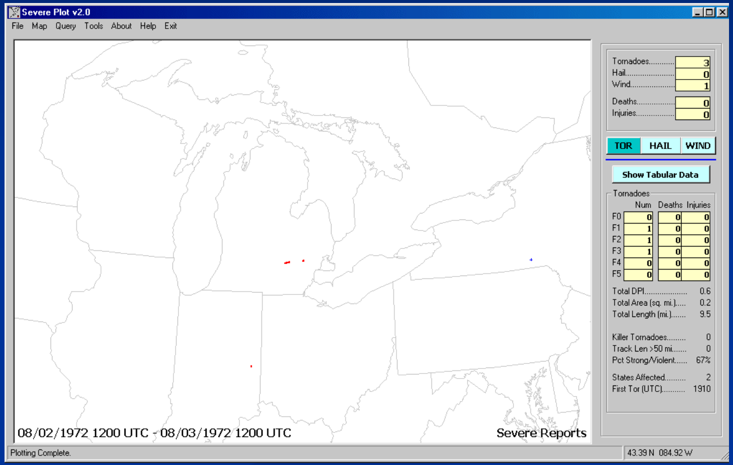


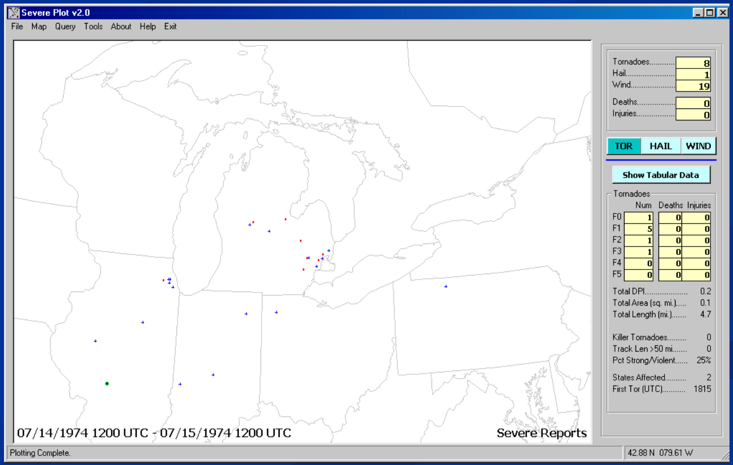
Type 2 Storm Reports

- Significant tornadoes and tornado outbreaks.
- However, generally speaking we are not seeing as dense a concentration of tornadoes as in Type 1.
- Also, with a few exceptions, in most cases we do not see the very long tornado path lengths that are almost exclusive to Type 1.

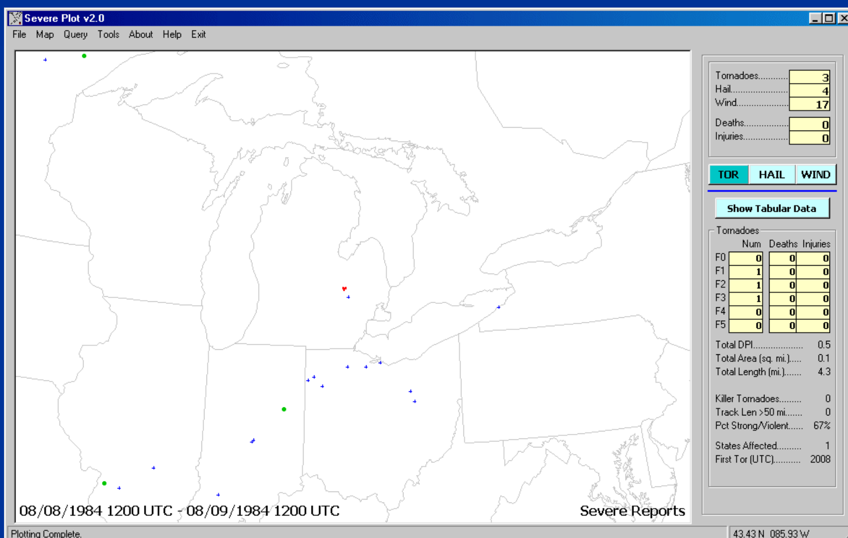
Type 3 Storm Reports

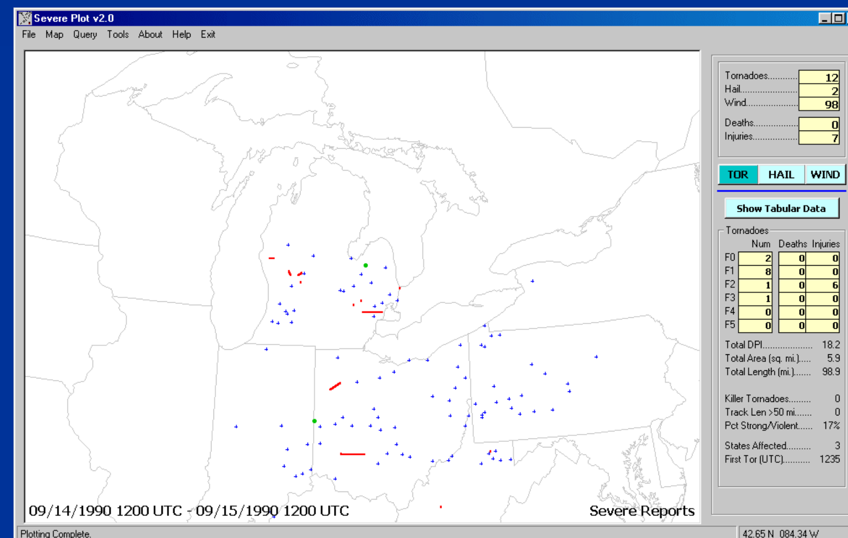






Type 3 Storm Reports





Type 3 Storm Reports

- Obviously, we do not have nearly as great a concentration of severe weather reports in Type 3.

- Type 3 tornadoes strike from July to September in high CAPE, fairly low LCL, and medium shear environments.